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AN ANALYSIS OF PRECIPITATION MEASUREMENTS ON MOUNTAIN WATERSHEDS

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[California Forest and Range Experiment Station, Forest Service, Berkeley, Calif., March 1937]

INTRODUCTION

The purpose of the study described in this paper was to ascertain, through analysis of precipitation measurements from gage systems upon mountainous watersheds, the reliability of computed rainfall averages, and on the basis of this analysis to decide what modifications of or additions to the original gage distributions are necessary in order to obtain results accurate within preestablished limits.

Since it is known that mountain precipitation varies considerably in amount for any single storm or season, even within quite limited areas, it is not possible to obtain exact data on total precipitation from a single raingage or even from several gages, but an average is required of measurements from sufficient instruments, well distributed over the watersheds in question, to furnish statistically reliable results. In the past, raingages have been distributed in mountain areas with little regard to a planned system; their location has been influenced mainly by proximity to a permanent habitation where continuous measurements could be made. It is not unusual to find only one gage in an area of 25 to 50 square miles. With distributions such as this it is impossible to apply a statistical analysis of the precipitation measurements for a watershed.

The present study was made on the San Dimas Experimental Forest. This research area on the Angeles National Forest has been equipped by the California Forest and Range Experiment Station for investigations into the relation of vegetation to water yield and erosion from mountain watersheds, with the ultimate objective of developing a system of management which will provide a maximum yield of usable water with minimum erosion. This tract of 17,000 acres (26.6 sq. miles) is located on the south slopes of the San Gabriel Mountains about 30 miles east of Los Angeles, California. Topographically the area is typical of a large part of the mountain range, with its sharp, V-shaped ridges and steep-sided canyons. The drainage system has developed to the climax. Elevations range from about 1,700 to 5,400 feet above sea level. (See fig. 1.)

Here the problem of precipitation measurements has been divided into two phases, distinct from one another by reason of their relative requirements of accuracy: first, the obtaining of precise precipitation data on two sets of three small watersheds; and second, the procurement of averages reliable within practical limits for 10 intermediate watersheds of varying size and complexity.

The arrangement of the areas studied in these two phases of the problem is shown in figure 5. The small, intensively studied watersheds, as outlined and labeled on the map, are Bell watersheds at the left, and Fern at the right. Intermediate compartments are the basins included within heavy dashed lines, and located by roman numerals. It should be noted that watershed IV is a large drainage unit including watersheds II and III as well as the unit surrounding numeral "IV" on the map, since these two watersheds drain into the lower section; and that watershed VI similarly includes watersheds I to V, together with the unit labeled "VI" on the map. In the following discussion the small and intermediate watershed groups are treated as independent units.

RAINGAGE DISTRIBUTION

Small watersheds

For the distribution of gages within the two groups of small drainages, contour trails were constructed at relatively short altitudinal intervals: 300 feet in Bell Canyon, and 250 feet in Fern Canyon. The selection of contours for this purpose was based upon knowledge of the two principal factors producing rainfall variations in mountains: elevation and surface relief. Beside sampling differences in elevation in a reasonably complete manner, contours traverse all topographic variations. With these trails available, it was necessary to distribute gages upon them at such intervals that variations in surface relief would be sampled as nearly as possible in proportion to the total watershed area occupied by each class of topographic variation.

As the best criterion of variation in surface relief within the triplicate watersheds "facets of slope" were taken—elementary topographic units, each of which, bounded on one side by a ridge and on the other by a canyon or draw, is characterized by a single aspect and degree of slope, with negligible variation. The facets existing within each watershed studied were delineated on an accurate contour map, and from their planimetered areas was determined the total area facing in each of eight compass directions within each watershed (table 1).

In order to obtain the fairest possible sampling of the areas in each aspect, gage locations were established mechanically on the map by several methods, using in each case the intersection of ruled lines with trails: (1) Polar coordinates at angles of 8° to each other, from the point of intersection of the axes of the small watershed units included in each area; (2) rectangular coordinates at 400-foot intervals, with gage locations set on trails at

[1] Now with Forest Service, Washington, D. C.

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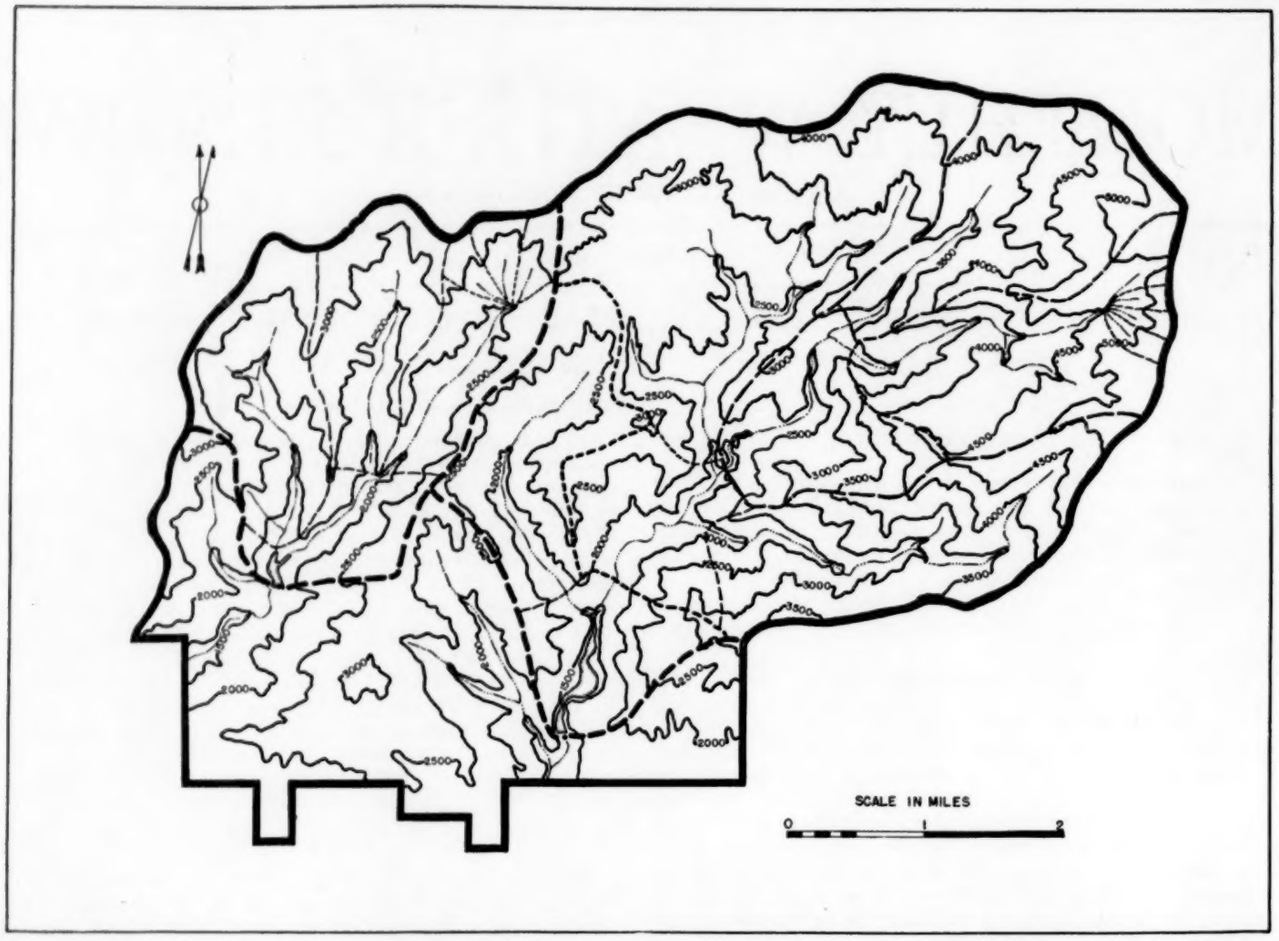

FIGURE 1.—Topographic map of San Dimas Experimental Forest with contour interval of 500 feet. Major drainage boundaries are indicated by heavy dashed lines; intermediate and minor watershed divides are shown by lighter dashes.

points nearest the corners of the rectangles; and (3) parallel lines at 300-foot horizontal intervals, drawn normal to the axis of each watershed (fig. 2).

A site description was obtained for each gage location established by each method, and these descriptions were compared with the actual average environmental characteristics of the watersheds. In comparing the allocation of gages to various aspects, for example, the percentage of gages assigned by each method to each class of topographic variation was determined, and the results compared statistically with the actual relief existing in each watershed (see table 1). The parallel-line method of location was adopted finally, as gage sites obtained by this method most closely fitted the general environmental characteristics of the watersheds and resulted in the smallest deviation of topographic location of instruments from the actual surface relief. Although method 2 gave a slightly better proportion of gages to the individual watersheds than method 3, it was believed that the superiority of method 3 in the matter of exposure outweighed the other considerations.

TABLE 1.—*Comparison of three methods of locating raingages with respect to aspect and watershed*

BELL CANYON TRIPLICATE WATERSHEDS

Aspect or watershed	Watershed area	Gage distribution, by—		
		Method 1	Method 2	Method 2
	Percent	*Percent*	*Percent*	*Percent*
North	0	0	0	0
Northeast	16.9	8.3	6.2	14.3
East	17.9	16.7	20.8	23.2
Southeast	17.6	29.2	22.9	19.6
South	18.8	18.7	14.6	17.9
Southwest	13.2	14.6	12.5	10.7
West	10.3	10.4	16.7	12.5
Northwest	5.3	2.1	6.3	1.8
Total	100.0	100.0	100.0	100.0
Deviation [1]		5.3	5.1	2.8
Watershed 1	32.3	31.3	31.3	31.6
Watershed 2	41.8	39.6	41.7	40.4
Watershed 3	25.9	29.1	27.0	28.0
Total	100.0	100.0	100.0	100.0

[1] Square root of mean squared deviation of percentages under each method, from the percentage of area in each aspect.

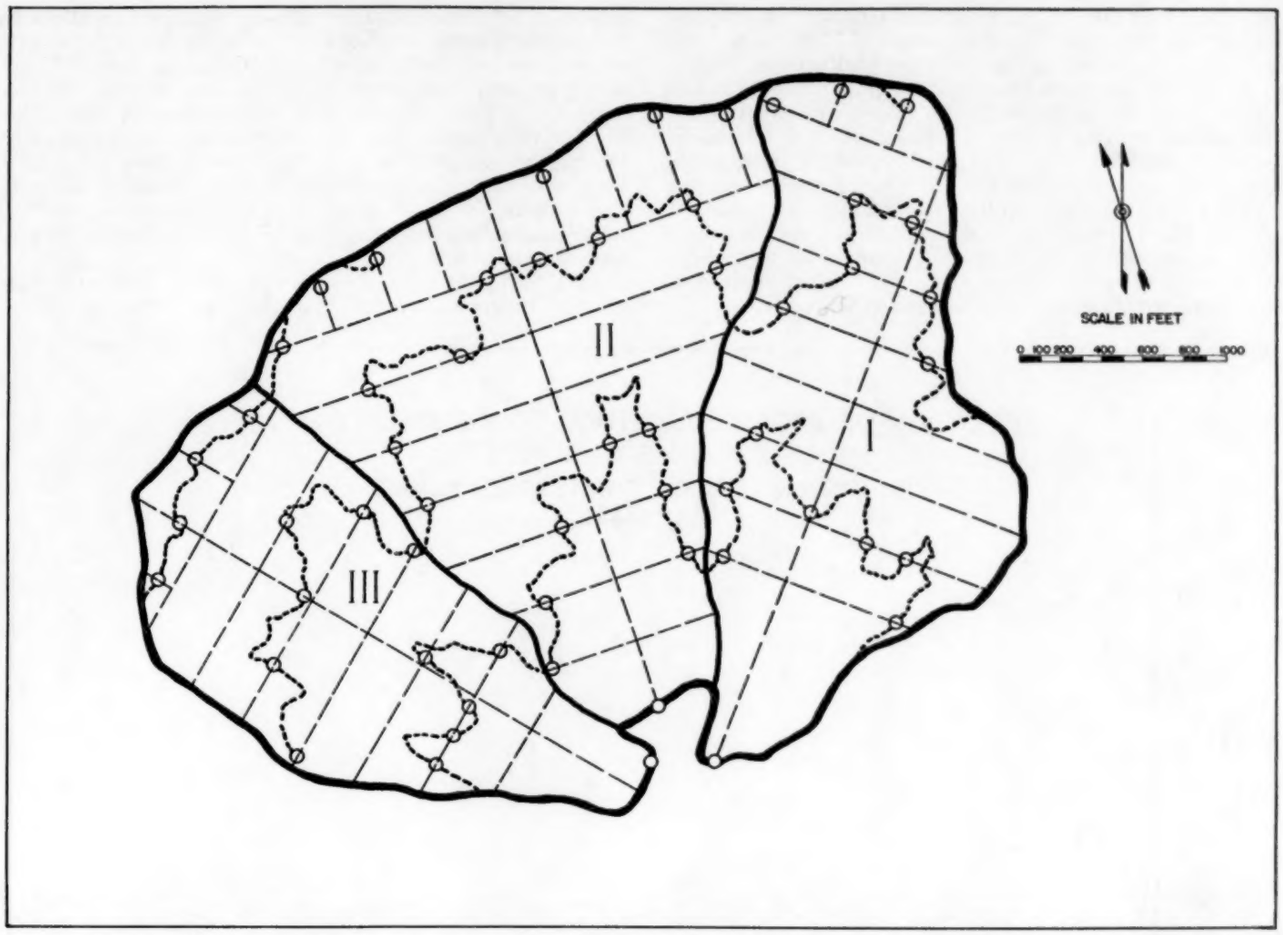

FIGURE 2.—Raingage distribution, Bell Canyon small watersheds. The method adopted for gage distribution is indicated by dashed lines; the gage locations by circles.

Intermediate compartments

As illustrated in figure 5, 10 intermediate watersheds in the experimental forest vary in area from a square mile up to approximately 14 square miles. In this large group, the number of gages which may be installed and measured after each storm, and therefore the accuracy of the resulting rainfall averages, are directly controlled by practical limitations of transportation and available man power. The objective in gage distribution was necessarily to obtain the best records possible within these practical limits.

For gage installation it was originally contemplated to construct a complete system of contour trails across the intermediate compartments at 2,100-, 3,100-, 4,100-, and 5,100-foot elevations, since a mechanical distribution of gages along contours at these intervals might be expected to give a good sample of precipitation. An examination of this large area demonstrated, however, that such a trail system fails to give a satisfactory lateral sampling of the forest. In broad, gently sloping basins large blank areas remain between 1,000-foot contours, while in a precipitous zone the same contour may enter a narrow canyon and return within a short horizontal distance. It was decided to utilize, in addition to the contour system, a number of grade trails and roads which satisfactorily fill in the blanks left by contours alone, and therefore give a more complete lateral sampling of the watersheds. Accordingly, during the period encompassed by the initial study of rain-gage distribution, about 175 gages were progressively set out in a mechanical distribution at half-mile intervals along all trails (contour and grade) and roads which were practical for the purpose.

METHOD OF ANALYSIS

Rainfall records obtained in the small watershed areas and each of the intermediate compartments of 10 representative storms occurring between December 1933 and April 1935, were analyzed statistically to determine their reliability, and, where they proved to be inadequate, to find the number of additional gages necessary to furnish a desired degree of accuracy. The dates of the 10 storms occurring in the 16 months of record are as follows:

Storm No.—	
1	December 30–31, 1933.
2	January 24, 1934.
3	February 22, 1934.
4	April 14–17, 1934.
5	June 5, 1934.
6	October 17, 1934.
7	November 15, 1934.
8	December 10, 1934.
9	January 10, 1935.
10	April 7, 1935.

Judgment as to the representative character of these storms was based upon their closeness of fit to an average curve in which, for all storms recorded on the experimental forest, the size of storm was plotted against the coefficient of variability of each storm. A curve illustrating the relationship, taken for Fern Watershed 1, is shown in figure 3. It will be seen that on the average there seems to be a clear relation between the size of any storm and its variability, as expressed by the coefficient of variation; and that this average relationship may be expressed by a curve approaching in form a rectangular hyperbola. The storms chosen for analysis (solid black points in figure 3) fit with reasonable closeness to this curve.

tistical constants. Actually, the removal of this effect by computing means weighted by areas within several altitudinal ranges, for instance, and by an analysis of variance, would demonstrate the reliability of data obtained from these gage distributions to be greater than that computed in this study. An analysis of variance made by Dr. George F. McEwen,[2] using five storms in the Bell triplicate area, gave weighted mean values agreeing closely with simple averages, and residual probable errors consistently less than two-thirds of the probable error of each simple average.

As a further check, isohyetal maps of Bell and Fern canyons were constructed for the 10 storms considered

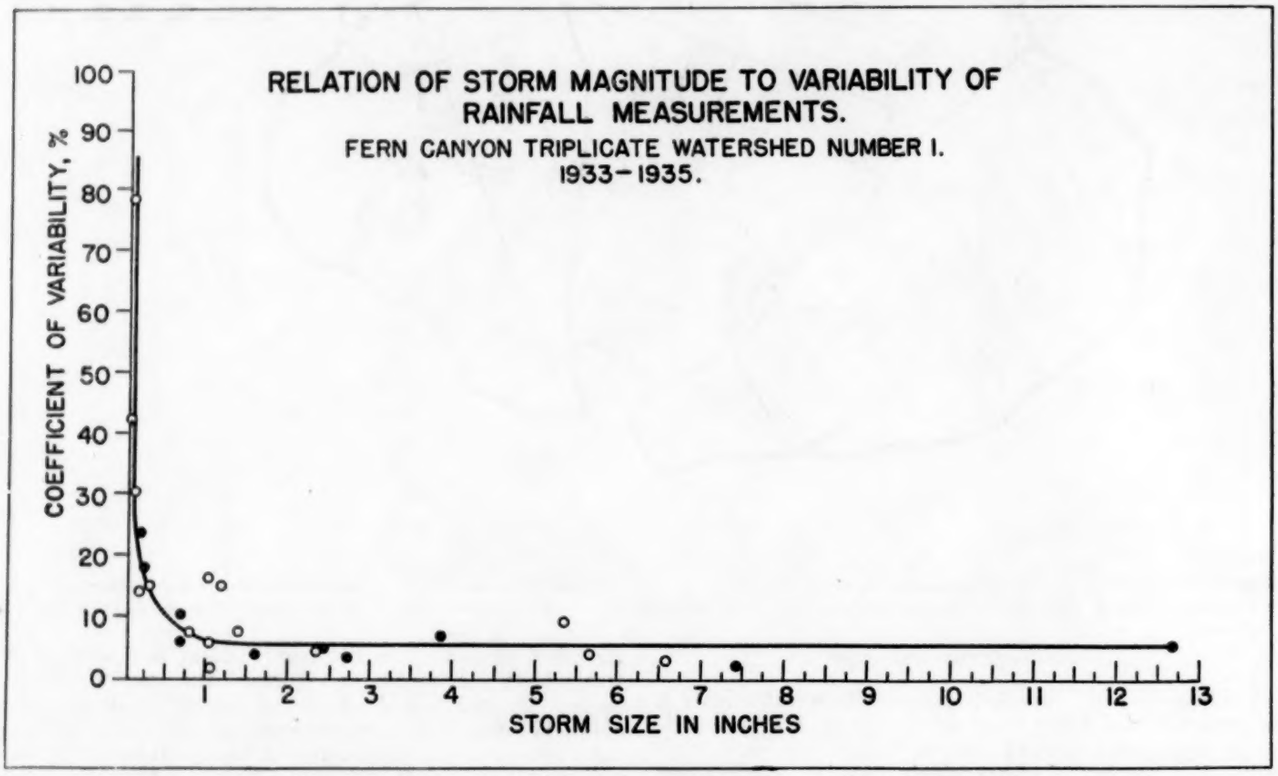

FIGURE 3.—Relation of Storm Magnitude to Variability of Rainfall Measurements. Fern Canyon Triplicate Watershed Number 1. 1933-1935.

Small watersheds

On these two small watershed groups, gages were installed in sufficient numbers (57 in Bell Canyon, and 47 at Fern) to insure a reasonably certain sample of all rainfall variability which might occur within each area.

Table 2 presents, for each storm in each watershed of the two triplicate areas, the statistical data involved in determining the accuracy of averages obtained with the existing gage distribution. Except for the smallest storms, these averages are reliable in general within 3 to 5 percent (2 times the standard error), although variation of individual readings from the mean may in some cases exceed 25 percent.

In this study of records for the small watersheds, no attempt has been made to isolate the effect of systematic variance, as with elevation, on the means and their standard errors. Maps covering 4 of the storms are shown in figure 4. Volumes of total precipitation catch were computed from the maps by planimetering the areas between adjacent isohyets, multiplying each area by the average of the two isohyets, and obtaining the sum of these products. These quantities were compared with volumes obtained by multiplying a simple average of gage readings by the area of watershed. This is in effect comparing a weighted average with a simple average. Table 3 shows the volumes obtained by both methods and the percent deviation.

The close agreement of results as computed by these three methods indicates that the present gage distributions in the small watersheds are so complete and representative that no alterations or additions to them are necessary.

[2] Scripps Institution of Oceanography, La Jolla, Calif. Paper presented to the American Meteorological Society, 1934.

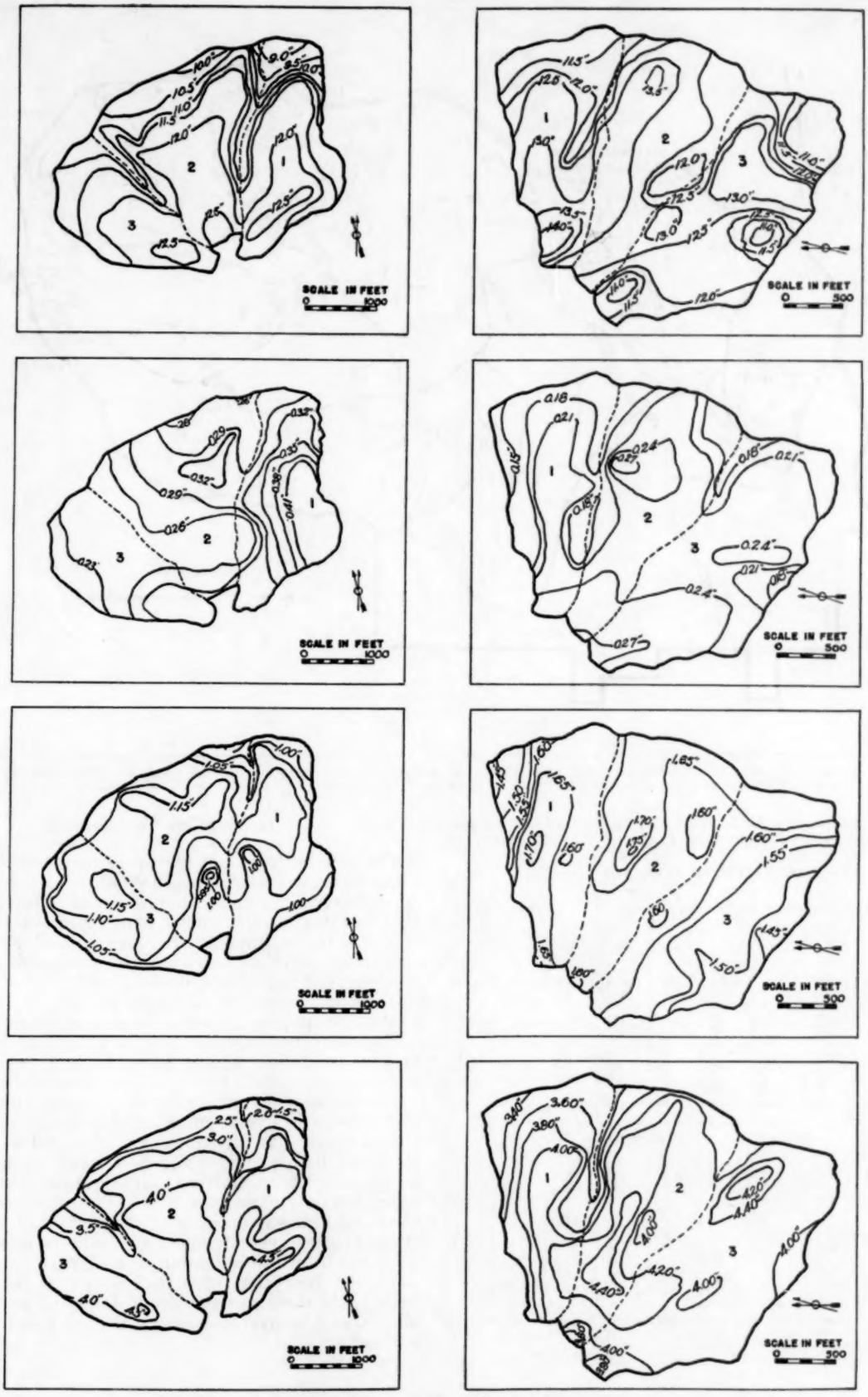

FIGURE 4.—Isohyetal maps for four storms in Bell (left) and Fern Canyons.

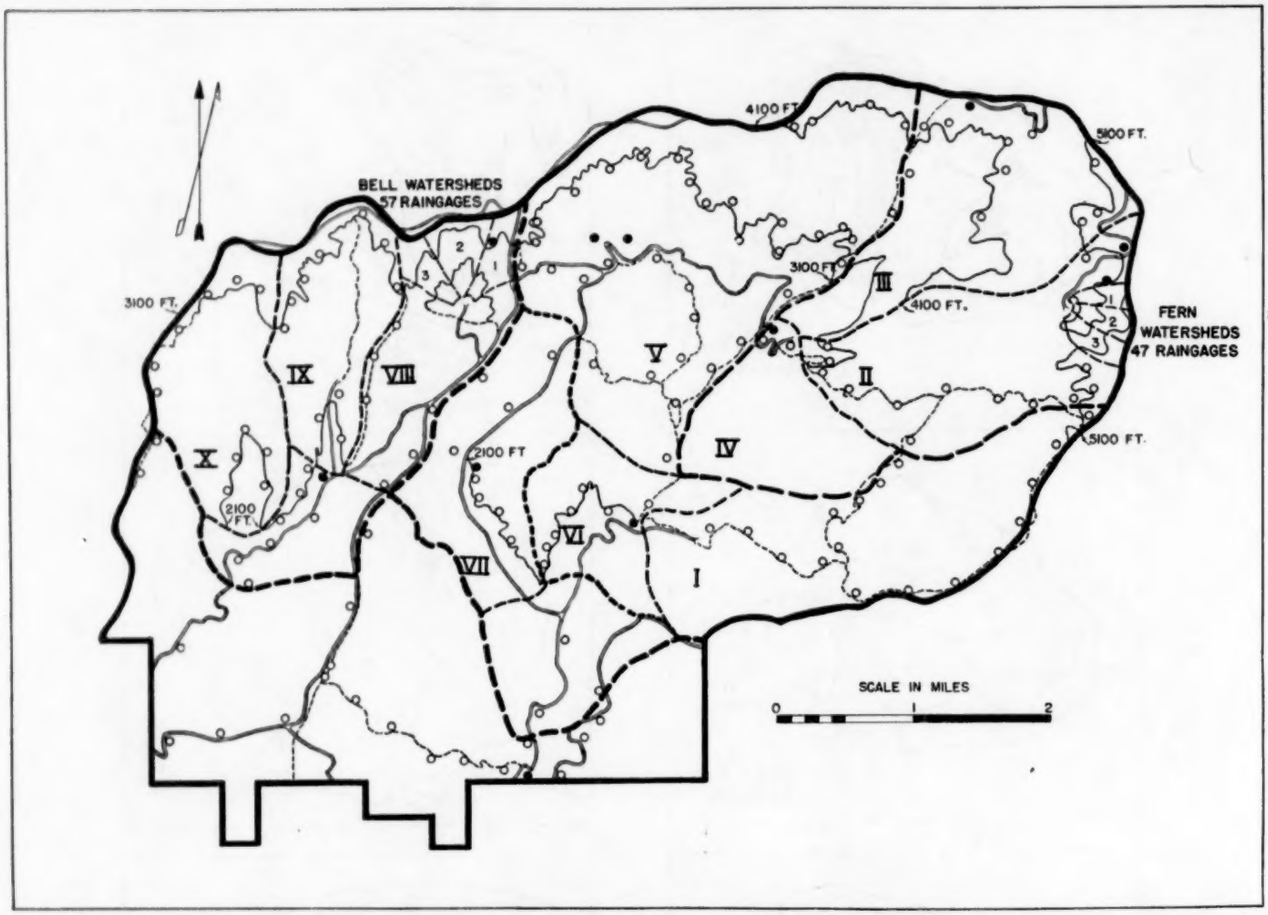

FIGURE 5.—Raingage distribution, San Dimas Experimental Forest. Heavy dashed lines are watershed boundaries; roman numerals, watershed numbers; light double lines are roads; light solid lines, contour trails; and light dashed lines are grade trails. Standard raingage locations are shown by small circles, and intensity gages by solid black dots.

TABLE 2.—*Statistical data for 10 storms, on the basis of existing gage distribution, from small watersheds 1, 2, and 3 of Bell and Fern Canyons* [1]

BELL SMALL WATERSHEDS

Storm No.	Catch of rainfall			Standard deviation			Standard error		
	1	2	3	1	2	3	1	2	3
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*
1	11.33	11.36	11.78	1.27	0.87	0.62	1.6	1.6	1.3
2	.34	.27	.26	.05	.02	.03	3.6	1.8	2.8
3	3.20	3.24	3.38	.28	.26	.21	2.1	1.6	1.7
4	.21	.23	.24	.03	.02	.01	3.1	1.6	1.3
5	.51	.52	.52	.03	.03	.02	1.4	1.2	1.0
6	6.41	6.51	6.88	1.01	.68	.48	3.8	2.2	1.8
7	2.56	2.52	2.43	.12	.09	.08	1.1	.8	.9
8	.62	.64	.68	.33	.05	.03	1.3	1.6	1.0
9	1.06	1.08	1.10	.05	.06	.04	1.2	1.2	1.0
10	3.25	3.45	3.84	.93	.66	.70	6.8	4.0	4.6

FERN SMALL WATERSHEDS

1	12.74	12.71	12.11	0.71	0.48	1.22	1.3	1.0	2.4
2	.19	.23	.23	.05	.03	.02	4.9	3.0	2.6
3	2.46	2.56	2.49	.11	.13	.18	1.0	1.3	1.7
4	.23	.21	.21	.04	.05	.04	5.7	5.7	4.3
5	.72	.78	.79	.04	.03	.06	1.1	1.0	1.7
6	7.46	7.47	7.43	.09	.09	.01	.3	.3	1.2
7	2.67	2.67	2.67	.09	.03	.02	.9	.3	.2
8	.71	.70	.69	.07	.04	.04	2.9	1.3	1.4
9	1.64	1.64	1.57	.06	.05	.07	1.1	.8	1.1
10	3.86	4.11	4.08	.27	.17	.20	1.6	1.0	1.2

[1] The number of gages on which these data are based are as follows: In Bell Canyon, 18 gages in No. 1 watershed; 22 in No. 2; and 16 in No. 3. In Fern Canyon, 13 gages in No. 1 watershed; 16 in No. 2; and 18 in No. 3.

Intermediate Compartments

The reliability of any group of measurements used to estimate the average of measurements of a random variable depends not only upon the number of observations available, but just as much upon a truly representative sampling of the variable studied. In the Bell and Fern triplicate areas such sampling was obtained with more than reasonable certainty, because of the large number of carefully distributed gages. Conditions in the 10 intermediate compartments, on the other hand, where gages are widely scattered over a large area, call for a check on the thoroughness of sampling before averages and their statistical constants may safely be used as an estimate of precipitation.

Comparison of simple rainfall averages with totals computed from isohyetal maps affords a means for making such a check. In any of the experimental watersheds, an isohyetal map provides the best weighted mean for the basin, since the rainfall contour lines take into account the effect not only of gages within each watershed, but also of those in adjacent drainages. The effect of a poorly distributed gage system, then, is a wide deviation of simple averages from the isohyetal, or weighted, results. Study of table 4 shows that, after the initial gage distribution was reasonably close to completion, large deviations between simple and isohyetal averages occurred only in rare instances.

TABLE 3.—*Comparison of precipitation catch computed from simple average with that obtained by isohyetal method on three small watersheds of Bell and Fern Canyons*

BELL SMALL WATERSHEDS

Storm No.	Catch on watershed 1			Catch on watershed 2			Catch on watershed 3		
	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation
	Acre-feet	*Acre-feet*	*Per cent*	*Acre-feet*	*Acre-feet*	*Per cent*	*Acre-feet*	*Acre-feet*	*Per cent*
1	72.05	71.47	−0.8	93.84	93.08	−0.8	59.38	59.24	−0.2
2	2.15	2.13	−.9	2.27	2.27	0	1.27	1.27	0
3	20.49	20.21	−1.4	26.87	26.68	−.7	17.00	16.93	−.4
4	1.39	1.38	−.7	1.94	1.93	−.5	1.23	1.21	−1.6
5	3.30	3.30	0	4.27	4.22	−1.2	2.65	2.64	−.4
6	43.92	43.11	−1.8	56.98	56.69	−.5	36.25	35.84	−1.1
7	12.16	12.18	+.2	20.92	20.75	−.8	16.13	16.02	−.7
8	3.94	3.95	+.3	5.36	5.32	−.7	3.37	3.43	+1.8
9	6.58	6.58	0	9.05	8.88	−1.9	5.53	5.58	+.9
10	21.47	20.54	−4.3	29.26	28.45	−2.8	19.46	19.33	−.7

FERN SMALL WATERSHEDS

1	34.45	35.20	+2.2	41.02	40.98	−0.1	51.33	51.61	+0.5
2	.52	.53	+1.9	.71	.73	+2.8	.97	.97	0
3	6.73	6.70	−.4	8.34	8.36	+.2	10.56	10.66	+.9
4	.59	.63	+6.8	.67	.69	+3.0	.89	.92	+4.5
5	1.98	2.02	+2.0	2.48	2.53	+2.0	3.28	3.37	+2.7
6	20.50	20.52	+.1	24.64	24.64	0	31.21	31.21	0
7	11.06	11.01	−.5	8.56	8.50	−.7	7.23	7.19	−.6
8	1.91	1.93	+.1	2.23	2.23	0	2.91	2.93	+.7
9	4.41	4.48	+1.6	5.25	5.22	−.6	6.58	6.56	−.3
10	10.46	10.62	+1.5	13.49	13.31	−1.3	17.34	17.24	−.6

Isohyetal maps were used also to test each gage location for local interference or lack of representative exposure. On these maps an unrepresentative gage reading stands out surrounded by an isohyet in the shape of a small ring. This is caused by the fact that the reading does not fit into the picture drawn from the surrounding gage readings. If one gage gave unrepresentative readings for a series of storms, it would be safe to assume that the gage was poorly located. Some of the gages gave questionable readings for single storms, but in all storms analyzed no gage was consistently out of line with the rest.

The standard error (S. E.) was used as a criterion of the reliability of averages obtained with the existing gage distribution, in the same way that this constant was employed for the small watershed areas. In addition, this concept was employed to compute the number of gages required to furnish a predetermined degree of reliability. Solving the standard error formula for "N," the number of instruments required is:

$$N=\left(\frac{\text{S. D.}}{\text{S. E.}}\right)^2$$

where S. E. is any standard error desired, such as 2.5 percent, 5 percent, or 10 percent of the average.

Table 5 presents, for each intermediate compartment, the average rainfall, standard deviation, and percent standard error for each storm; also the number of existing gages and of those required in each case to give a standard error of 2.5, 5, or 10 percent of the average. On watersheds II (Fern) and VIII (Bell), two gages were allowed for the area covered by the small watersheds and included in the total of existing gages for these areas. Computation of the standard error and number of gages required was omitted for all storms in which insufficient gage readings were available to give accurate figures.

Storms 2 and 4, both small in size, show considerable variation throughout each of the 10 intermediate compartments. These two storms, each less than 0.5 inch in amount, comprise only about 2.5 percent of the total precipitation for the season 1933–34. By referring to table 5 it can be seen that to obtain a standard error less than 2.5 percent for such small storms, a great number of gages would be necessary; whereas for the larger storms, almost enough gages exist at the present time on most of the intermediate watersheds. The question that must be answered, therefore, is how much weight small storms should have in influencing the determination of the standard errors to be required, and therefore the number of gages necessary to give these standard errors.

TABLE 4.—*Comparison of precipitation catch computed by using simple average with that obtained by isohyetal method on 10 intermediate watersheds of entire forest*

Storm No.	Watershed I			Watershed II			Watershed III			Watershed IV			Watershed V		
	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation
	Acre-feet	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*
1	1,371.07	1,417.01	+3.3	1,425.44	1,442.15	+1.2	1,209.66	1,212.84	+0.3	3,282.50	3,373.77	+2.8	2,400.48	2,388.77	−0.5
2	76.60	73.24	−4.4	31.08	30.79	−.9	22.53	21.88	−2.9	74.53	73.34	−1.6	79.33	82.05	+3.4
3	281.72	292.96	+4.0	280.27	286.12	+2.1	288.40	298.75	+3.6	710.69	730.44	+2.8	707.88	720.83	+1.8
4	54.52	59.89	+9.8	37.49	37.39	−.3	31.65	27.54	−13.0	91.57	86.65	−5.4	74.18	74.78	+.8
5	127.90	124.69	−2.5	101.62	98.56	−3.0	92.89	89.75	−3.4	251.88	240.33	−4.6	180.41	171.72	−4.8
6	837.23	841.36	+.5	800.54	790.22	−1.3	757.92	789.17	+4.1	1,906.89	1,979.24	+3.8	1,485.77	1,504.18	+1.2
7	350.83	340.64	−2.9	315.45	308.86	−2.1	309.85	299.71	−3.3	748.63	749.47	+.1	630.27	635.28	+.8
8	75.10	76.79	+2.3	90.33	87.81	−2.8	96.56	95.65	−.9	217.16	218.88	+.8	160.77	163.34	+1.6
9	128.99	128.07	−.7	163.60	165.07	+.9	146.39	148.86	+1.7	368.94	379.42	+2.8	263.98	264.48	+.2
10	481.33	492.73	+2.4	455.46	441.93	−3.0	439.75	414.30	−5.8	1,106.46	1,061.46	−4.1	920.26	924.16	+.4
	Watershed VI			Watershed VII			Watershed VIII			Watershed IX			Watershed X		
1	7,679.20	7,614.70	−0.8	968.73	1,029.73	+6.3	980.32	962.67	−1.8	835.18	896.52	+7.3			
2	254.86	256.52	+.7	31.51	28.74	−8.8	25.11	25.11	0	24.53	26.47	+7.9			
3	1,831.92	1,876.15	+2.4	203.82	219.25	+7.6	235.05	224.79	−4.4	247.20	242.67	−1.8	290.33	310.02	+6.8
4	231.63	242.88	+4.9	15.62	15.23	−2.5	15.98	16.59	+3.8	15.75	15.33	−2.7	22.83	22.88	+.2
5	606.05	585.71	−3.4	47.84	44.72	−6.5	37.87	39.17	+3.4	31.63	32.08	+1.4	35.22	36.28	+3.0
6	4,506.02	4,551.65	+1.0	533.88	559.82	+4.9	517.80	505.44	−2.4	494.63	497.88	+.7	572.19	562.59	−1.7
7	1,847.42	1,879.95	+1.8	235.99	239.50	+1.5	186.88	189.54	+1.4	166.70	169.05	+1.4	197.03	197.45	+.2
8	476.49	481.57	+1.1	48.76	49.20	+.9	45.68	45.88	+.4	45.60	45.99	+.9	56.59	58.20	+2.8
9	816.64	824.01	+.9	80.78	80.82	0	76.10	73.16	−3.9	71.02	70.39	−.8	83.45	81.26	−2.6
10	2,679.11	2,648.89	−1.1	287.92	308.90	+7.3	257.52	248.97	−3.3	252.74	258.74	+2.4	311.91	301.80	−3.2

TABLE 5.—*Rainfall averages and statistical constants, and the number of gages required to give various degrees of accuracy, in 10 intermediate watersheds*

Watershed and storm No.	Observations	Rainfall	Standard deviation	Standard error	Gages required if ratio of S. E. to mean is—		
					2.5 percent	5 percent	10 percent
Watershed I:	*Number*	*Inches*	*Inches*	*Percent*	*Number*	*Number*	*Number*
1	9	9.56	1.377				
2	9	.48	.151				
3	16	1.97	.132	1.68	8	2	1
4	17	.40	.131	7.95	172	43	11
5	16	.85	.100	2.94	23	6	2
6	16	5.69	.483	2.12	16	3	1
7	14	2.49	.228	2.08	14	4	1
8	16	.52	.073	3.96	32	8	2
9	14	.89	.091	2.69	17	5	1
10	16	3.33	.252	1.89	10	3	1
Watershed II:							
1	9	12.01	.957				
2	10	.26	.030				
3	15	2.34	.180	1.98	10	3	1
4	15	.30	.138	11.71	331	83	21
5	16	.81	.102	3.12	25	7	2
6	16	6.75	.713	2.64	18	5	2
7	16	2.54	.245	2.41	15	4	1
8	16	.70	.077	2.72	20	5	2
9	15	1.35	.184	3.53	30	8	2
10	14	3.61	.410	3.05	21	6	2
Watershed III:							
1	5	10.06	1.745				
2	5	.21	.045				
3	5	2.65	.464				
4	6	.22	.099				
5	8	.75	.035	1.65	4	1	1
6	9	6.52	1.006	5.14	38	10	3
7	10	2.45	.154	1.99	7	2	1
8	11	.82	.100	3.67	24	6	2
9	11	1.22	.159	3.95	13	4	1
10	10	3.42	.535	4.94	39	10	3
Watershed IV:							
1	15	11.24	1.530				
2	16	.25	.064				
3	23	2.36	.408	3.60	48	12	3
4	24	.29	.130	9.23	327	81	21
5	27	.80	.089	2.16	21	5	2
6	28	6.53	.871	2.52	29	8	2
7	29	2.51	.214	1.59	12	3	1
8	30	.73	.118	3.03	43	11	3
9	29	1.21	.386	5.93	164	41	11
10	26	3.50	.497	2.79	33	8	2
Watershed V:							
1	22	9.91	.836				
2	22	.31	.083				
3	31	2.86	.355	2.23	25	7	2
4	31	.30	.095	2.86	164	41	11
5	28	.68	.122	3.37	51	13	4
6	29	5.91	.433	1.36	9	3	1
7	34	2.55	.110	.74	202	75	19
8	34	.66	.108	2.89	43	11	3
9	33	1.05	.101	1.67	15	4	1
10	34	3.62	.298	1.41	11	3	1
Watershed VI:							
1	50	10.43	1.450				
2	49	.32	.132				
3	71	2.50	.452	2.15	53	14	4
4	73	.32	.125	4.63	251	63	16
5	78	.74	.139	2.12	56	14	4
6	80	6.04	.739	1.37	24	6	2
7	84	2.55	.247	1.01	15	4	1
8	87	.65	.129	2.19	64	16	4
9	84	1.08	.280	2.85	109	28	7
10	82	3.46	.426	1.36	25	6	2
Watershed VII:							
1	8	12.19	.737				
2	7	.28	.022				
3	6	2.58	.263				
4	5	.18	.023				
5	9	.51	.134	8.67	110	27	7
6	10	6.46	.399	1.96	7	2	1
7	10	2.67	.121	1.42	4	1	1
8	10	.57	.035	1.95	7	2	1
9	10	.92	.036	1.24	3	1	1
10	10	3.46	.749	6.86	77	19	5
Watershed VIII:							
1	4	11.10	1.202				
2	7	.32	.064	7.40	62	16	4
3	8	3.06	.396	4.58	27	7	2
4	5	.23	.016	3.03			
5	6	.53	.048	3.72			
6	7	6.79	.456	2.54	8	2	1
7	8	2.56	.159	2.19	7	2	1
8	8	.61	.047	2.72	10	3	1
9	8	1.00	.066	2.33	7	2	1
10	8	3.44	.351	3.61	17	5	1
Watershed IX:							
1	4	12.94	.130				
2	4	.39	.036				
3	11	3.55	.283	2.40	11	3	1
4	11	.23	.043	5.63	56	14	4
5	11	.46	.046	3.02	16	4	1
6	11	7.41	.484	1.97	8	2	1
7	11	2.48	.215	2.62	12	3	1
8	11	.67	.054	2.45	11	3	1
9	11	1.03	.112	2.28	19	5	2
10	11	3.68	.513	4.20	32	8	2

TABLE 5.—*Rainfall averages and statistical constants, and the number of gages required to give various degrees of accuracy, in 10 intermediate watersheds*—Continued

Watershed and storm No.	Observations	Rainfall	Standard deviation	Standard error	Gages required if ratio of S. E. to mean is—		
					2.5 percent	5 percent	10 percent
Watershed X:	*Number*	*Inches*	*Inches*	*Percent*	*Number*	*Number*	*Number*
1							
2							
3	3	3.56	.308				
4	6	.30	.050				
5	6	.43	.020				
6	12	6.66	.693	3.01	18	5	2
7	12	2.43	.122	1.44	4	1	1
8	11	.70	.051	2.19	9	2	1
9	12	1.01	.121	3.96	23	6	2
10	11	3.60	.672	5.63	56	14	4

Records of rainfall for the city of Glendora covering 54 years give an average annual rainfall of 22.85 inches, of which only 9.3 percent (S. D., 5.4) fell in storms of less than half an inch and 22.3 percent (S. D., 13.3) in storms of less than 1 inch. From these data it may be estimated that rains of half an inch or less may seldom be expected to exceed 20 percent of the annual precipitation (mean+2 S. D.); and that storms of an inch or less will not be expected to exceed 50 percent of the total annual precipitation. From this knowledge, and to compromise with practical expediency in gage distribution, it was decided to set up the following arbitrary requirements of accuracy for storms of various magnitudes: For storms below 0.5 inch, a standard error of 10 percent; storms between 0.5 and 1 inch in size, 5 percent; and all larger storms, 2.5 percent.

Table 6 presents the number of gages at present installed in each intermediate watershed, and the approximate number which will be necessary in order to give the required accuracy of results. The latter figure is the simple average of the numbers apparently required for each of the 10 storms. Figure 5 is a map of the entire forest showing location of trails, rain gages and watershed boundaries.

By the beginning of the 1935–36 rainy season, the gage distribution was completed according to the requirements set up in the above analysis for watersheds I–VIII. To check the adequacy of sampling by these gages, a study was made of all storms of any appreciable size during this season, occurring on the following dates:

Storm No.—

11	October 14, 1935.
12	November 17–18, 1935.
13	December 3–4, 1935.
14	December 29, 1935.
15	February 1–2, 1936.
16	February 10–20, 1936.
17	February 22–23, 1936.
18	March 21, 1936.
19	March 24, 1936.
20	March 30, 1936.
21	April 3–4, 1936.

Table 7 shows that the standard errors of these rainfall averages were well within desirable limits for most storms. It will be noted in this respect that number of gages required as set up in table 6 are based on an average figure, and therefore, storms with an unusually high variability will fall outside the required limits of accuracy. (See standard errors *underlined*, in table 7.)

TABLE 6.—*Number of gages required statistically in 10 intermediate watersheds*

Watershed No.	Present number gages	Total number gages required [1]	Watershed No.	Present number gages	Total number gages required [1]
I	17	10	VI	87	34
II	16	16	VII	87	34
III	11	18	VIII	8	10
IV	30	40	IX	11	12
V	34	37	X	12	20

[1] Average number necessary to give standard errors (S. E.$_M$) of 2½, 5 and 10 percent, respectively, for storms over 1 inch, between ½ and 1 inch, and under ½ inch. In computing these averages, storms were omitted in which variation was not completely sampled.

Present number of gages in watershed VI greater than number required, because it includes those in watersheds I, IV, and V.

TABLE 7.—*Rainfall averages and statistical constants, 10 intermediate watersheds, season 1935–36*

Storm No.	Watershed I				Watershed II			
	Gages	Rainfall	Standard deviation	Standard error	Gages	Rainfall	Standard deviation	Standard error
	Number	*Inches*	*Inches*	*Percent*	*Number*	*Inches*	*Inches*	*Percent*
11	9	0.28	0.081	9.7	8	0.30	0.087	10.2
12	13	.40	.043	3.0	13	.45	.065	4.0
13	11	.33	.098	9.0	17	.31	.111	8.7
14	20	.84	.144	3.8	20	.83	.071	2.0
15	24	3.91	.574	*5.0*	20	4.62	.518	2.6
16	24	10.71	.620	1.2	17	11.04	.598	1.3
17	23	1.86	.159	1.8	20	1.97	.189	2.1
18	23	.37	.101	5.7	22	.28	.102	7.8
19	23	.61	.080	2.7	22	.64	.087	2.9
20	23	1.54	.150	2.0	23	1.99	.195	2.0
21	24	1.92	.166	1.8	23	2.24	.253	2.4
	Watershed III				Watershed IV (including II and III)			
11	2	0.23	0.010	3.1				
12	14	.35	.035	2.6	28	0.40	0.070	3.3
13	15	.28	.070	6.5	35	.30	.090	5.2
14	14	.74	.073	2.6	43	.80	.082	1.6
15	15	4.09	.627	*5.9*	43	4.30	.604	2.1
16	15	10.58	.975	2.4	40	10.76	.768	1.1
17	15	1.79	.123	1.8	44	1.89	.177	1.4
18	18	.24	.085	8.5	50	.28	.099	5.0
19	18	.61	.071	2.7	50	.62	.079	1.8
20	19	1.96	.262	*5.1*	52	1.94	.224	1.6
21	18	2.26	.153	1.6	51	2.20	.232	1.5
	Watershed V				Watershed VI (I, IV, V, inclusive)			
11	10	0.30	0.053	5.7	30	0.29	0.070	4.5
12	31	.36	.043	2.2	72	.38	.058	1.8
13	35	.28	.036	2.1	88	.30	.073	2.6
14	35	.84	.173	3.5	105	.82	.130	1.5
15	37	3.62	.700	*5.2*	111	3.94	.642	1.5
16	36	10.57	1.119	1.8	107	10.51	1.136	1.0
17	36	1.78	.244	2.3	110	1.84	.202	1.0
18	37	.28	.056	3.3	117	.29	.079	2.5
19	32	.60	.045	1.3	112	.61	.069	1.1
20	35	1.82	.141	1.3	117	1.81	.238	1.2
21	37	2.26	.155	1.1	119	2.14	.247	1.1

TABLE 7.—*Rainfall averages and statistical constants, 10 intermediate watersheds, season 1935–36*—Continued

Storm No.	Watershed VII				Watershed VIII			
	Gages	Rainfall	Standard deviation	Standard error	Gages	Rainfall	Standard deviation	Standard error
	Number	*Inches*	*Inches*	*Percent*	*Number*	*Inches*	*Inches*	*Percent*
11	4	.27	.006	1.1	6	.30	.012	1.6
12					9	.36	.025	2.3
13	9	.33	.023	2.3	9	.32	.018	1.9
14	9	.77	.040	1.7	9	.75	.074	3.3
15	9	3.93	.251	2.1	8	3.60	.208	2.0
16	9	11.67	.406	1.2	9	11.54	1.045	*3.0*
17	9	1.86	.151	2.7	9	1.63	.152	*3.1*
18	9	.24	.042	5.8	9	.25	.039	5.1
19	9	.61	.053	2.9	9	.63	.036	1.9
20	9	1.82	.135	2.5	9	1.87	.178	*3.1*
21	9	2.10	.219	*3.5*	9	2.24	.238	*3.5*
	Watershed IX				Watershed X			
11								
12	10	.43	.089	6.6	9	.44	.054	4.1
13	10	.33	.022	2.1	11	.37	.030	2.4
14	3	.85	.040	2.7	5	.81	.203	*11.5*
15	10	4.02	.826	*6.5*	10	3.94	.643	*5.2*
16	10	12.58	.818	2.1	10	12.90	1.047	2.6
17	10	1.36	.184	*4.5*	11	1.38	.260	*5.7*
18	10	.20	.073	*11.5*	11	.28	.080	8.6
19	10	.65	.052	2.5	11	.64	.061	2.9
20	10	2.07	.116	1.8	11	2.03	.169	2.5
21	10	2.31	.232	*3.2*	11	2.20	.245	*3.4*

Storm No.	Entire forest above flood-control dams				Storm No.	Entire forest above flood-control dams			
	Gages	Rainfall	Standard deviation	Standard error		Gages	Rainfall	Standard deviation	Standard error
	Number	*Inches*	*Inches*	*Percent*		*Number*	*Inches*	*Inches*	*Percent*
11	50	0.31	0.107	4.8	17	180	1.70	0.285	1.2
12	125	.39	.062	1.4	18	187	.29	.102	2.5
13	153	.31	.060	1.5	19	179	.61	.067	.8
14	157	.81	.126	1.2	20	188	1.84	.313	1.2
15	178	3.80	.698	1.4	21	191	2.10	.349	1.2
16	176	10.90	1.301	.9					

In table 8, the deviation of rainfall catch computed by simple averages from those obtained by isohyetal maps are excessive only in small storms, for which only a part of the rain gages had been read and these not well enough distributed to sample adequately individual watersheds.

TABLE 8.—*Comparison of precipitation catch computed by using simple average with that obtained by isohyetal method on 10 intermediate watersheds, extensive system, season 1935–36*

Storm No.	Watershed I			Watershed II			Watershed III			Watershed IV			Watershed V		
	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation	Isohyetal method	Simple average	Deviation
	Acre-feet	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*	*Acre-feet*	*Acre-feet*	*Percent*
11	42.08	40.91	−2.8	32.25	36.51	+13.0	28.33	27.63	−2.5				75.80	75.57	−.3
12	60.44	59.18	−2.1	52.73	54.64	+3.6	43.54	42.51	−2.4	119.59	121.54	+1.6	86.03	90.56	+5.3
13	43.41	47.45	+9.3	36.88	37.82	+2.5	33.11	33.78	+2.0	90.16	90.64	+.5	72.45	71.98	−.6
14	116.36	121.95	+4.8	101.41	102.51	+1.1	92.83	91.80	−1.1	253.09	252.63	−.2	208.96	212.58	+1.7
15	580.44	548.49	−5.5	552.66	555.76	+.6	505.86	499.21	−1.3	1,286.55	1,301.48	+1.2	925.12	913.18	−1.3
16	1,569.94	1,571.97	+.1	1,354.01	1,358.79	+.4	1,305.19	1,317.21	+.9	2,969.83	3,019.55	+1.7	2,751.15	2,705.53	−1.7
17	279.79	273.56	−2.2	242.10	242.87	+.3	222.02	220.62	−.6	582.20	581.79	−.1	453.31	452.13	−.3
18	48.61	54.21	+11.5	30.74	33.83	+10.3	29.55	28.67	−3.0	81.83	86.00	+5.1	70.24	72.13	+2.7
19	84.75	90.14	+6.4	77.83	78.98	+1.5	73.06	74.71	+2.3	186.87	190.61	+2.0	153.37	151.93	−.9
20	220.86	226.96	+2.8	243.50	241.72	−.7	243.59	238.39	−2.1	599.05	593.49	−.2	456.94	462.32	+1.2
21	275.39	280.70	+1.9	279.70	274.52	−1.9	272.92	276.34	+1.3	670.71	673.52	+.4	582.13	575.44	−1.1
	Watershed VI			Watershed VII			Watershed VIII			Watershed IX			Watershed X		
11	210.74	219.03	+3.9	24.67	22.00	−10.8	23.82	22.83	−4.1	21.35	35.21	+64.9			
12	286.25	290.28	+1.4				26.57	27.21	+2.4	29.29	29.40	+.4	36.27	36.76	+1.3
13	224.23	226.41	+1.0	29.21	28.45	−2.6	23.73	24.53	+3.4	23.42	22.49	−4.0	32.65	30.59	−6.3
14	615.16	624.92	+1.6	64.43	63.47	−1.5	56.67	60.42	+6.6	50.63	59.25	+17.0	60.29	66.91	+10.5
15	3,031.85	3,028.04	−.1	335.43	327.89	−2.2	298.41	287.21	−3.8	280.71	277.37	−1.2	349.13	328.06	−6.0
16	8,148.88	8,059.26	−1.1	925.58	954.98	+3.2	927.15	945.05	+1.9	871.48	868.63	−.3	1,038.68	1,069.14	+2.9
17	1,416.21	1,409.33	−.5	147.58	153.79	+4.0	120.93	132.28	+9.4	95.13	92.92	−2.3	117.19	114.96	−1.9
18	212.50	225.35	+6.0	20.50	20.43	+.3	18.27	20.50	+12.2	15.65	14.16	−9.5	24.63	23.60	−4.2
19	457.13	465.95	+1.9	53.10	52.89	−.4	44.01	48.12	+9.3	45.75	44.85	−2.0	53.93	52.80	−2.1
20	1,349.65	1,379.32	+2.0	152.10	156.70	+3.0	144.74	143.83	+.6	144.70	143.22	−1.0	170.25	167.82	−1.4
21	1,629.03	1,629.99	0	168.94	177.48	+5.1	172.32	170.34	−1.1	161.52	159.23	−1.4	188.80	182.58	−3.3

CONCLUSIONS

1. A mechanical distribution of gages such as described in this study appears to give reasonably thorough sampling of rainfall variation in mountain watersheds. Additions to or modifications of such distributions in order to improve sampling may be made by a study of isohyetal maps and statistical constants based upon a preliminary rain gage installation.

2. The gage system employed iu this experiment gives results accurate for most storms measured, within practical limits.

3. In order to avoid employing an impracticably large number of rain gages, the requirements for accuracy of averages should be modified in inverse relation to the size and importance of storms.

4. With a system of gages distributed so as to sample rainfall variation as thoroughly as possible, a simple average of their readings will agree within close limits with rainfall catch computed from isohyetal maps. Application of the former method requires much less time and skill than the isohyetal method.

PRELIMINARY RESULTS OF PILOT-BALLOON ASCENTS AT LITTLE AMERICA

By G. GRIMMINGER

[Weather Bureau, Washington, D. C., June 1939]

The meteorological observations at Little America during the two Byrd Expeditions include 969 pilot-balloon ascents. These have been worked up fairly completely and the results of the two years of observation combined, although it has not yet been possible to give the results the study they deserve, it will be of interest to point out some of the more obvious facts which they disclose.

From the combined data for both the expeditions, there have been computed the mean direction and mean velocity as well as the resultant direction, resultant velocity, and stability. The above quantities have also been worked out for each of the 4 seasons.

The mean direction should be distinguished from the resultant direction; the former is computed by using the frequency with which the different directions occur, while the latter is computed by using the velocities as well as the directions and gives the direction of the vector representing the resultant air transport.

The stability, mentioned above, refers to directional stability, and is computed by forming the ratio $\frac{\text{resultant velocity}}{\text{mean velocity}} \times 100$; this gives a measure of the steadiness of the wind direction, for, if the wind always blows from the same direction, the resultant velocity and the mean velocity are the same and the stability is 100 percent. If, on the other hand, the directions are equally distributed and also have the same velocity, the resultant velocity and therefore the stability will be zero.

TABLE 1.—*Mean values of direction, velocity, and stability of the wind at Little America* [1]

[Based on 2 years of observation, 1929 and 1934]

Altitude (meters)	Number of observations	Mean direction from—	Resultant direction from—	Mean velocity	Resultant velocity	Stability	Mean direction—resultant direction
				m. p. s.	*m. p. s.*	*Percent*	
12,000	4	N 19° W.	N 7° W.	17.5	6.8	39	−12°
11,000	9	N 8° W.	N 18° W.	11.6	5.7	49	10°
10,000	30	N 8° E.	N 5° W.	8.9	3.2	36	13°
9,000	65	N 12° E.	N 14° W.	11.0	2.2	20	26°
8,000	115	N 10° W.	N 59° W.	13.0	3.7	28	49°
7,000	172	N 23° W.	N 66° W.	12.5	3.2	26	43°
6,000	236	N 37° W.	N 70° W.	11.2	2.4	21	33°
5,000	318	N 55° W.	S 85° W.	9.7	1.2	12	40°
4,000	415	S 1° E.	S 28° W.	8.4	1.0	12	−29°
3,000	549	S.	S 29° W.	7.7	1.4	18	−29°
2,500	625	S 9° E.	S.	7.4	1.5	20	−9°
2,000	704	S 17° E.	S 9° E.	7.4	2.0	27	−8°
1,500	772	S 18° E.	S 9° E.	7.3	2.2	30	−9°
1,000	854	S 20° E.	S 10° E.	7.4	2.0	27	−10°
750	883	S 25° E.	S 16° E.	7.5	2.0	27	−9°
500	924	S 34° E.	S 30° E.	7.7	2.3	30	−4°
250	957	S 35° E.	S 40° E.	7.1	2.9	41	5°
Surface	969	S 22° E.	S 40° E.	4.0	1.8	45	18°

[1] Latitude 78°34′06″ south, longitude 163°55′58″ west.

In table 1 are given the mean values of the direction, velocity, and stability of the wind at standard levels for the 2 years of observation, 1929 and 1934. The vertical distribution of the mean velocity is shown in figure 1, from which it is seen that a maximum value is reached at about 7,700 m. From the studies of Peppler (**1**) and Dobson (**1A**), this wind maximum can be related to the

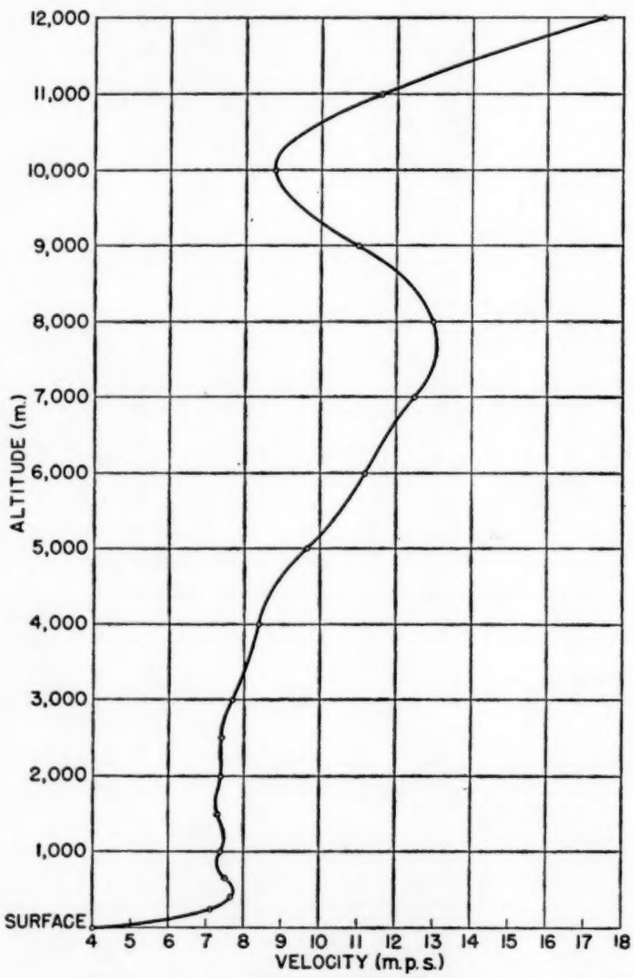

FIGURE 1.—Vertical distribution of the mean wind velocity at Little America.

height of the tropopause. From the results of his study Peppler gave the following table.

Height of tropopause	8	9	10	11	12	13	14 km.
Height of wind maximum	8.0	8.7	9.3	10.0	10.6	11.3	12.0 km.
Difference	0.0	0.3	0.7	1.0	1.4	1.7	2.0 km.

In the region in which the observations were made there is thus a relation between the height of the wind maximum and the height of the tropopause, such that the two practically coincide for low values of the tropopause height.

Although Peppler's study was based on data for Central Europe, there seems to be no reason why a similar relation should not hold in general for the other latitudes as well; and in the polar regions, where there is much evidence pointing to a relatively low tropopause, one may reasonably expect the height of the wind maximum and that of the tropopause to be more or less coincident. Thus the mean height of the tropopause for the year can be considered as equal to, or perhaps slightly greater than, 7,700 m.

The only other available upper air-wind data in the Antarctic consist of 120 pilot-balloon ascents made during the drift of the ship *Deutschland* in the Weddel Sea during the German Antarctic Expedition in 1911–12. The results of these ascents as given by Barkow (**2**) show a maximum wind velocity at about 7,500 m., which is in very good agreement with the value of 7,700 m. found at Little America. In the North Polar region we have the observations made by Sverdrup (**3**) during the Maud Expedition, which show a velocity maximum at 8,000 m., which is in good agreement with the above values for the southern hemisphere.

The separate years, 1929 and 1934, at Little America likewise show good agreement, the average height of the velocity maximum being about 7,900 m. in 1929, and 7, 500 m. in 1934. There is a well-marked variation in height of the tropopause from summer to winter of about 1,100 m., the tropopause being higher in summer and lower in winter, which agrees with results of temperature soundings in other latitudes.

The above results do not agree with the estimate by Shaw (**4**) who, in a chart showing the distribution of the tropopause over the globe, placed this below 4 km in winter over the south polar area. As stated above, on the basis of the wind observations, the height of the tropopause over the Antarctic is essentially the same as over the Arctic, and Shaw's estimate appears to be about 3.5 km too low.

The increase in velocity indicated in figure 1 at 11 and 12 km is possibly not representative of average conditions, but rather the result of the very small number of observations at these levels.

Some insight into the reason for the velocity maximum at or near the tropopause can be gained by a consideration of the effect of horizontal gradients of temperature upon the variation of wind with height. Letting the y-axis point north and the x-axis east, and assuming geostropic conditions, the following equations are easily derived (*5*):

$$\frac{\partial u}{\partial z}=\frac{1}{\rho f T}\left(\frac{\partial p}{\partial y}\frac{\partial T}{\partial z}-\frac{\partial p}{\partial z}\frac{\partial T}{\partial y}\right) \quad (1)$$

$$\frac{\partial v}{\partial z}=\frac{-1}{\rho f T}\left(\frac{\partial p}{\partial x}\frac{\partial T}{\partial z}-\frac{\partial p}{\partial z}\frac{\partial T}{\partial x}\right) \quad (2)$$

where u is the East-West component of the velocity and v the North-South component.

Assuming as a first approximation that in sufficiently high layers of the atmosphere, conditions are symmetric with respect to longitude then $\frac{\partial p}{\partial x}$, $\frac{\partial T}{\partial x}$, and consequently $\frac{\partial v}{\partial z}$, are zero, and we need consider only $\frac{\partial u}{\partial z}$. From equation (1) we can now investigate the sign of $\frac{\partial u}{\partial z}$ in the upper troposphere. Using mean values of the horizontal gradients of pressure and temperature along a meridional cross section[1], and mean values of the vertical gradients of pressure and temperature, it is found that in the upper troposphere $\frac{\partial u}{\partial z}$ is positive. In the stratosphere $\frac{\partial T}{\partial z}$ can be taken as zero and since the horizontal temperature gradient is reversed, $\frac{\partial u}{\partial z}$ becomes negative. Thus, at or near the tropopause $\frac{\partial u}{\partial z}$ changes sign from positive to negative which means that u must have a maximum value at this altitude. The wind maximum is thus essentially the result of the reversed temperature gradient in the stratosphere.

The result of combining all the upper air wind data for the 2 years of observation at Little America shows that the average wind direction is southeasterly in the lower levels and undergoes a clockwise rotation with increasing altitude, thus becoming in turn southeasterly, southernly, southwesterly, westerly, northwesterly, and northerly; the northerly winds occurring at the highest levels. This turning of the wind direction is indicated by both the mean direction and the resultant direction.

There is a fairly well-marked minimum in the stability at 4 and 5 km., indicating that the greatest variability in wind direction occurs at these levels; this is also the altitude where the *mean* wind direction changes from one having a southerly component to one having a northerly component. It thus appears that on the average there is a transition layer between 4 and 5 km. separating the troposphere into two parts.

Thus in the lower part of the troposphere there is a south component of the resultant wind which is fairly constant up to about 1,500 m. and then decreases gradually to zero at about 5 km. At all levels above this there is a north component which gradually increases with elevation up to 10 km., which is probably as far as the computations can be considered as significant owing to the small number of observations at the higher levels.

In the last column of table 1 is given the difference between the mean direction and the resultant direction, the positive sign indicating that the mean direction is in advance of the resultant direction in the sense of a clockwise rotation. One might expect that the greatest difference between the mean and the resultant direction would occur where the stability is a minimum. This apparently is not the case, since the greatest difference occurs at 8 km., that is, at the approximate level of the tropopause. The minimum stability on the other hand seems to be related to the change in sign of the difference between the two directions. In this particular case the effect of the change in signs is such that the level of the minimum stability coincides with the level where the change of the direction difference with altitude has its maximum value, namely, 69° per km.

[1] See *Handbuch der Klimatologie*, Band 1, Teil F., S. 66, 67.

Considering the east-west components of the resultant wind, there is an east component in the lower layers which gradually decreases with elevation and becomes zero at 2,500 m. Above this there is a west component at all levels, and this has a maximum at around 8 km. corresponding to the altitude of the maximum mean wind.

As a result of the decrease of temperature southward in the upper layers, there will also be a decrease of pressure so that the westerly winds are to be associated with a polar cyclone. Or, looking at this in another way, if the wind conditions in the upper layers are considered as existing more or less symmetrically around the continent, then the westerly winds indicate the presence of a polar cyclone in the upper levels.

The question now arises as to what layers are to be included in the cyclonic circulation. If we consider this to consist of all those layers having a westerly component of motion, the polar cyclone will then begin at about 2,500 m. and extend to 10 km. or higher. Assuming the resultant wind to be geostrophic, the center of the cyclone for the layer between 2.5 and 5 km. will be situated somewhere over West Antarctica; from 5 to 8 km. the center will be more or less centered over the polar plateau itself, while above 8 km. the center will be over East Antarctica corresponding to the large northerly component in the motion.

The easterly component of motion in the lower layers has usually been interpreted as being the result of a polar anticyclone; so that since the east component in the yearly average vanishes at 2,500 m., the depth of the anticyclone cannot be greater than this.

In the past, since pilot-balloon data were lacking, it was customary to assume that the average direction of the winds at upper levels was essentially the same as that derived from the observed directions of cloud movement. In order to test the validity of such an assumption, table 2, based on 2 years of observation at Little America, has been prepared.

TABLE 2.—*Comparison of mean direction of cloud motion and mean direction of wind at Little America*

	Lower clouds (St.)	Number of observations	Intermediate clouds (A St)	Number of observations	Upper clouds (Ci St)	Number of observations
Mean height of clouds, meters.	892	157	3,031	72	5,070	15
Mean direction of clouds.[1]	N. 50° E.	557	N. 58° E.	278	N. 7° W.	134
Mean direction of wind.	S. 23° E.	854	S.	549	N. 55° W.	318
Difference	107°		122°		−48°	
Resultant direction of wind.	S. 13° E.	854	S. 29° W.	549	S. 85° W.	318
Difference	117°		151°		−88°	

[1] From surface observations.

The mean cloud heights were determined from the pilot-balloon ascents; the table contains the differences: mean cloud direction minus mean wind direction; and mean cloud direction minus resultant wind direction. It is seen that these differences are large, amounting to 122° and 151°, respectively, for the level of the intermediate clouds at 3,000 m, and 48° and 88° respectively for the level of the upper clouds at 5,000 m. These results certainly seem to indicate that any deduction of the average direction of air flow from observations of cloud motion may be greatly in error, especially when the mean cloud altitude is near or within the levels of minimum stability. This is not surprising since conditions producing an overcast of ASt or CiSt can hardly be considered as representing the average. It thus seems, especially at certain levels, that the mean direction of the isobars when taken to be the same as the mean direction of cloud motion can be very much in error.

The polar anticyclone must be manifested by winds having an easterly component, and it is reasonable to associate greater intensity of this anticyclone with greater easterly wind components. In table 3 are given the east-west components in summer, winter, and the three coldest months; and it is seen that in the lower layers the east components are much smaller in winter than in summer, while for the three coldest months it is found that the resultant wind direction has no east component at all. This is hardly what one would expect, since, as a result of the intense radiational cooling in the winter, it would appear that the anticyclonic circulation should be intensified rather than weakened. In fact the common explanation of the polar anticyclone is that the cooling of the air lowers the isobaric surfaces and the resulting inflow aloft raises the surface preasure (over what is was before) thus leading to increased anticyclonic circulation. Incidentally this explanation is hardly consistent with the fact that the sea-level pressure, at least in the Ross Sea area, is distinctly lower in the coldest months.

TABLE 3.—*East-west components of the resultant wind velocity at Little America*

Altitude (meters)	Summer (December, January, and February)	Winter (June, July, and August)	3 coldest months (July, August, and September)
	m. p. s.	*m. p. s.*	*m. p. s.*
9,000	0.72	----------	3.49
8,000	4.68	----------	2.43
7,000	3.24	3.87	3.69
6,000	1.97	4.42	2.87
5,000	1.43	2.07	1.35
4,000	.75	.96	1.84
3,000	−.19	.97	1.73
2,500	−.72	.92	1.75
2,000	−1.00	.22	1.54
1,500	−1.15	.00	1.54
1,000	−.87	.12	1.44
750	−1.22	−.10	1.35
500	−1.94	−.37	.99
250	−2.40	−.78	.71
Surf	−1.47	−.43	.37
	East=− West=+		

That the decrease in the east component in the cold season is real, and not the result of having made the balloon ascents during particular weather types, is substantiated by the results of the hourly surface-wind observations which are given in the following table:

Mean surface wind direction

	Summer	Winter	3 coldest months
From hourly values	S. 50° E.	S. 11° E.	S. 7° W.
From pilot-balloon ascents	S. 26° E.	S. 5° E.	S. 16° W.

The mean direction as computed from the hourly values shows the decrease in the east component from summer to winter and also the absence of any east component during the 3 coldest months. For the sake of comparison there is given in the second row the mean surface direction as computed from the pilot-balloon ascents and it is seen that these show substantial agreement with the results of the hourly values indicating that the results of the pilot-balloon ascents may be considered as giving a satisfactory representation of average conditions.

It will be noted that in the upper layers the west components are larger in winter from 4 to 7 km, and in the 3 coldest months from 4 to 9 km, excepting at 8 km, where a weakening is indicated.

Since most of the Antarctic Continent is in the form of an elevated land mass with a downward slope from the Pole to the edges of the continent, radiational cooling in the lower layers must lead to a drainage of cold air outward and as a result of the deflective influence of the earth's rotation this drainage effect alone would act to increase the east component of the atmospheric motion in the lower layers. The outward drainage to the north in the lower layers will lead to an inflow aloft toward the south which, as a result of the deflective influence, would be indicated by northwesterly winds in the upper levels. As stated below the *annual* means show very clearly winds with south and east components at the low levels and with north and west components at the higher levels and agrees qualitatively with the concept of the outward drainage of cold air below and a compensating inflow aloft. During the colder months, one should therefore expect an increase in the south component in the lower layers and increased north components aloft. In table 4 are given the north-south components of the resultant wind velocity in summer winter, and the 3 coldest months. It is seen that the south components are distinctly larger in winter than in summer up to 1,000 m; this is even more pronounced during the coldest period and extends to 2,000 m. In the upper layers it is seen that there are larger north components in winter than in summer at 7 and 8 km. and in the coldest period from 5 to 9 km.

TABLE 4.—*North-south components of the resultant wind velocity at Little America*

Altitude (meters)	Summer (December, January, and February	Winter (June, July, and August)	3 coldest months (July, August, and September)
	m. p. s.	*m. p. s.*	*m. p. s.*
9,000	3.81	----------	3.80
8,000	3.16	4.17	3.47
7,000	1.47	2.79	1.58
6,000	1.20	.68	1.46
5,000	.49	−.21	1.07
4,000	−.95	−.29	−.04
3,000	−1.31	−.27	−.73
2,500	−1.69	−.52	−1.36
2,000	−2.14	−1.35	−2.19
1,500	−2.24	−2.04	−2.67
1,000	−1.61	−2.59	−3.46
750	−1.53	−2.96	−3.74
500	−1.53	−2.96	−3.74
250	−1.80	−3.03	−3.57
Surface	−1.34	−1.31	−1.50
South=− North=+			

In general, the seasonal variation of the north-south components agrees with what would be expected if the circulation over the continent were controlled mainly by the drainage of the cold lower layers. The seasonal variation of the east-west components in the upper layers also agrees with this; but that of the lower layers does not, since as pointed out above the east components are smaller in winter and are lacking entirely during the 3 coldest months. In high latitudes where the Coriolis effect attains its maximum value, any drainage of the cold air toward the north in the lower layers should be acted on by the deflecting influence to a maximum extent so as to produce southeast or east winds. Just why these east components do not appear in the coldest months when the drainage should be a maximum is not clear.

It should be emphasized, however, that the direction of the drainage flow must depend largely on the direction of slope of the surface. Little America is situated on the Ross Shelf Ice, which is a large area of low, level surface surrounded by high land to the west, east, and south, that has a general downward slope into the shelf ice area. Thus, there is South Victoria Land to the west, Marie Byrd land to the east, and the Queen Maud Range and Polar Plateau to the south. This area is therefore well situated to act as a drainage basin for the cold air from these high slopes and to serve as an outlet for it to the north. This is supported by the fact of the larger south component in the air transport found in the coldest months. Along the western side of the shelf ice the damming effect of the high South Victoria land is sufficient to prevent any easterly component in the movement which would arise as a result of the earth's rotation and to cause the main motion there to take place in a north-south direction. It is doubtful, however, if this effect would be present at Little America since it is 400 or more miles to the east.

It should also be pointed out that easterly winds can be produced by cyclonic as well as anticyclonic pressure distributions, and it would be important to separate, if possible, the contribution of these two types of pressure distribution in producing easterly winds. It is also important to study the relation between the eastward moving depressions and the release of large masses of cold air.

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TROPICAL DISTURBANCE OF JUNE 12–16, 1939

By JEAN H. GALLENNE

[Marine Division, Weather Bureau, August 1939]

The first tropical disturbance of 1939 attained only moderate intensity, but moved in a rather unusual course from the Gulf of Honduras northward and north-northwestward to the east Gulf coast.

The earliest report of disturbed conditions in connection with this depression was received on the morning of June 12, through the Mexican weather service at Chetumal, placing the center near latitude 18°45′ N. and longitude 87° W. During the afternoon of the same day, although no reports of strong winds were received, vessels in the area just east of the Yucatan Peninsula reported squally weather conditions, with moderate to rough seas.

The Amer. S. S. *Carrillo* at 7 a. m. (E. S. T.) of June 12, near latitude 18.7° N. and longitude 86.6° W. reported a barometer reading of 29.77 inches; east-southeast winds, force 5; slight drizzle, with rough sea. At 7 a. m. (E. S. T.) of the following day, the *Carrillo*, then in the easterly quadrant of the disturbance, encountered east and southeast winds of force 7–8 accompanied by very rough seas.

The center of the depression, by evening of June 12, was near Cozumal Island, where there had been a fall in pressure from 29.88 inches at the morning observation, to 29.61 inches at 7 p. m. (E. S. T.).

During the period from the morning of June 12 until the evening of June 14 the disturbance moved slowly northward.

The Pan American Airways Observer at San Julian, located on the extreme western tip of Cuba, reported south wind, force 7, with a rainfall of 10 inches, during the night of June 12–13. On the morning of the 13th, the S. S. *Alabama*, near latitude 25.3° N. and longitude 85.8° W., recorded a falling barometer; fresh gales from the east-southeast and southeast, with overcast skies and rain. By noon the wind had increased from force 8 to force 9; this was the highest wind reported in connection with this disturbance. The lowest barometer reading during the progress of the disturbance (29.54 inches) was observed on the evening of June 14, on the American Steamship *Kofresi*, near latitude 29.5° N. and longitude 87.6° W. This vessel reported that during that period she met with heavy rain squalls, moderate gales, and rough seas.

During the 24 hours following the evening of the 14th, the center of the disturbance described a small left-hand loop, then resumed a north-northwestward movement on the night of June 15, which carried the depression inland, over Mobile, Ala., on the morning of the 16th.

The explanation of this loop by R. A. Dyke, Forecaster in charge of our New Orleans Office, is as follows:

> The westward turn at the beginning of the loop early on the night of the 14th–15th was attended by a tendency toward equalization of pressure along the coast north of the disturbance. The pressure at Pensacola rose from 29.66 at 7:30 p. m. (E. S. T.) of the 14th to 29.68 at 9 p. m., while the pressure at Mobile fell from 29.74 to 29.70 inches. However, instead of movement to the coast, as expected, the disturbance continued to move in a small curve which brought it slightly farther south on the morning of the 15th.
>
> Until the movement of the disturbance was halted off Pensacola, the straight northward progress was evidently under the influence of upper winds in line with those over Florida, where the western portion of an upper anticyclonic circulation gave upper winds from the south. The northward drift prevailed as far west as New Orleans up to 14,000 feet on the 12th.
>
> With northward advance the winds aloft from Florida westward to New Orleans came under the influence of the disturbance. At the same time the winds aloft from 8,000 to 14,000 feet were moving anticyclonically over Texas and the Lower Mississippi Valley. The center of this upper anticyclonic circulation moved east-northeastward from Texas and Oklahoma to eastern Kentucky, or thereabouts, from the 14th to the 16th, and the upper winds over the Lower Mississippi Valley became easterly instead of northeasterly, except over New Orleans, where winds in the afternoon of the 15th were northeast up to 27,000 feet, with the upper winds showing velocities of 30 to 42 miles per hour. In the early morning of the 16th, the upper winds at elevations of 8,000 to 12,000 feet from Montgomery, Ala., to Memphis, Tenn., and Little Rock, Ark., had veered to southeasterly, while winds over New Orleans, under the influence of the disturbance, had backed to northerly. During the shift of the center of the upper anticyclonic circulation from the Southern Plains to a more eastern position the northward movement of the disturbance was halted by blocking winds; but when the upper circulation became central farther east the upper winds favored the resumption of northward movement. Indeed, the blocking winds apparently forced the disturbance farther southward so as to form the small loop described.

At Mobile, Ala., at 9:37 a. m. (E. S. T.) of June 16, as the center moved inland, an abrupt wind-shift from north to south was observed. The wind was of only moderate force. At 7:30 p. m. (E. S. T.) of the 16th, its center lay to the southwest of Meridian, Miss.; the disturbance thereafter advanced to the northward, and merged with an extra-tropical LOW pressure area.

There was no loss of life reported in connection with this disturbance, except that a boy fell into the swollen waters of the Peace River near Wauchula, Fla., and was drowned.

The first advisory in connection with this disturbance was issued from the Weather Bureau Office at Jacksonville, Fla., at 9:30 p. m. (E. S. T.) of June 12, and as the depression passed through the Gulf of Mexico, frequent timely warnings and advisories were issued from New Orleans, La.

Chart XIII, shows the situation on the morning of June 13, and the track of the disturbance.

THE CHAMPLIN-ANOKA, MINNESOTA, TORNADO

By M. R. HOVDE

[Weather Bureau, Minneapolis, Minn., June 1939]

On Sunday afternoon, June 18, 1939, between 3 and 4 p. m., a destructive tornado crossed the northwestern portion of Hennepin County and entered southern Anoka County. Several villages and the small city of Anoka were in the path of the funnel-shaped cloud; and death, injuries, and destruction were left in its wake.

The towns of Champlin and Anoka, center of greatest damage, are located on the Mississippi river, 17 miles north of Minneapolis. The combined population of 5,000 is practically all centered in Anoka, which is on the east bank of the river; the small village of Champlin is on the west bank.

The studies of Finley, Henry, and the Climatological Service of the Weather Bureau indicate that 122 tornadoes have occurred within the limits of Minnesota during 40 years of record, an annual average of 3. The Champlin-Anoka storm must be placed among the most disastrous 10 in loss of life and value of property destroyed.

The tornado was first observed southwest of Corcoran in Hennepin County and traveled in a northeasterly course through Maple Grove, Champlin, Anoka, and Cedar, a distance of 25 miles. The storm struck Anoka at 3:20 p. m. and its last fury was spent in Cedar at 3:38 p. m. These times indicate a speed of translation of about 30 miles per hour.

The occurrence of the storm can best be explained by the convective instability of the air that prevailed over this region during the 18th. At 6:30 a. m. C. S. T. that morning, a disturbance was centered over eastern North Dakota. Tropical maritime air has been transported northward into western and southern Minnesota. About 2 kilometers above this moist air was a Superior air mass overrunning from the southwest. As shown by the meteorograph sounding made at Fargo, the lapse rate of this Superior air was almost the dry adiabatic. When this sounding was plotted on the Rossby diagram it showed that the atmosphere in the warm sector of this disturbance was extremely convectively unstable. In fact, a layer of air would have had to be lifted only a little more than 1 kilometer to realize absolute instability.

This amount of lifting could have been easily accomplished by the steep and very distinct cold front that moved eastward through Minnesota that afternoon. Thunderstorms were numerous in the east-central coun-

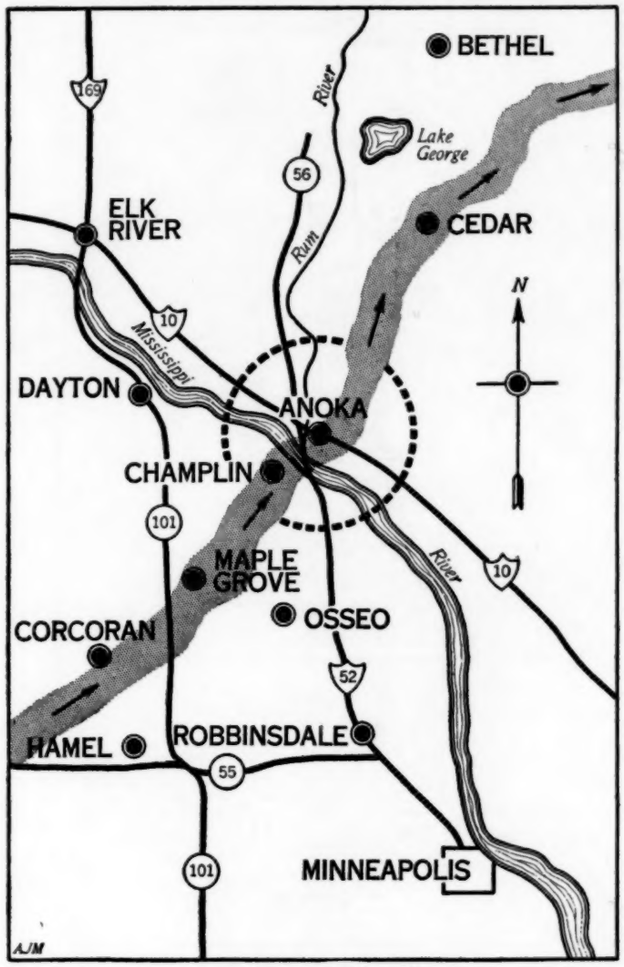

FIGURE 1.—Path of the tornado.

ties and were attended by severe hail and excessive precipitation in many localities. The tornado was an attendant to one of these storms.

Debris was carried as high as 300 feet and small articles of furniture, clothing, and papers were picked up in various places 50 to 70 miles distant.

The first destruction and fatalities occurred near Corcoran where four dwellings were demolished and four persons met death when their automobile was thrown 1,000 feet and smashed to pieces. In the Maple Grove district, seven farmhouses were damaged or destroyed. The tornado continued its northeasterly course to Champlin where several houses were completely demolished; 1 death and 30 injuries resulted. The storm now crossed the Mississippi river and many witnesses saw the river "dry up" as the waters were lifted and wind velocities were so great as to prevent the flow and the return of water until the funnel cloud had reached the opposite bank. Entering Anoka at Second Avenue the tornado cloud moved up Third Avenue and cut a diagonal swath three blocks wide through the city, leveling houses, trees, and buildings. According to a survey by the *Anoka Union Newspaper*, 240 families and 1,450 persons were affected by this disaster.

The State militia took charge of policing Anoka and remained on duty until June 26. Traffic through the city was resumed a week after the storm when 25,000 automobiles and 100,000 persons visited the scenes of destruction.

The table gives the frequency of tornadoes, tornado deaths, and property losses for early periods in Minnesota and for the past 15 years. From this tabulation it will be seen that this tornado was a major disaster; it caused 9 deaths, 222 injuries, and $1,200,000 property damage.

Tornadoes in Minnesota

[Frequency of tornadoes, tornado deaths, and property losses]

Year or period	Number of tornadoes	Loss of life from tornadoes	Aggregate reported property losses
1874–81	21	[1]	[1]
1889–97	26	35	$595,000
1916–23	12	99	4,767,000
1924	2	3	500,000
1925	3	0	137,500
1926	0	0	
1927	2	0	100,500
1928	5	6	1,190,000
1929	4	8	1,460,000
1930	5	1	235,000
1931	2	2	212,000
1932	2	0	700,000
1933	0	0	
1934	5	1	929,200
1935	[2] 15	3	673,700
1936	5	3	891,000
1937	5	1	212,500
1938	7	0	546,000
1939 [3]	[4] 1	[5] 9	[6] 1,200,000

[1] Unknown.
[2] Tornado character doubtful in 7 storms.
[3] For 6 months, January-June, inclusive.
[4] Champlin-Anoka tornado of June 18.
[5] 222 persons injured.
[6] Estimate of disaster committee.

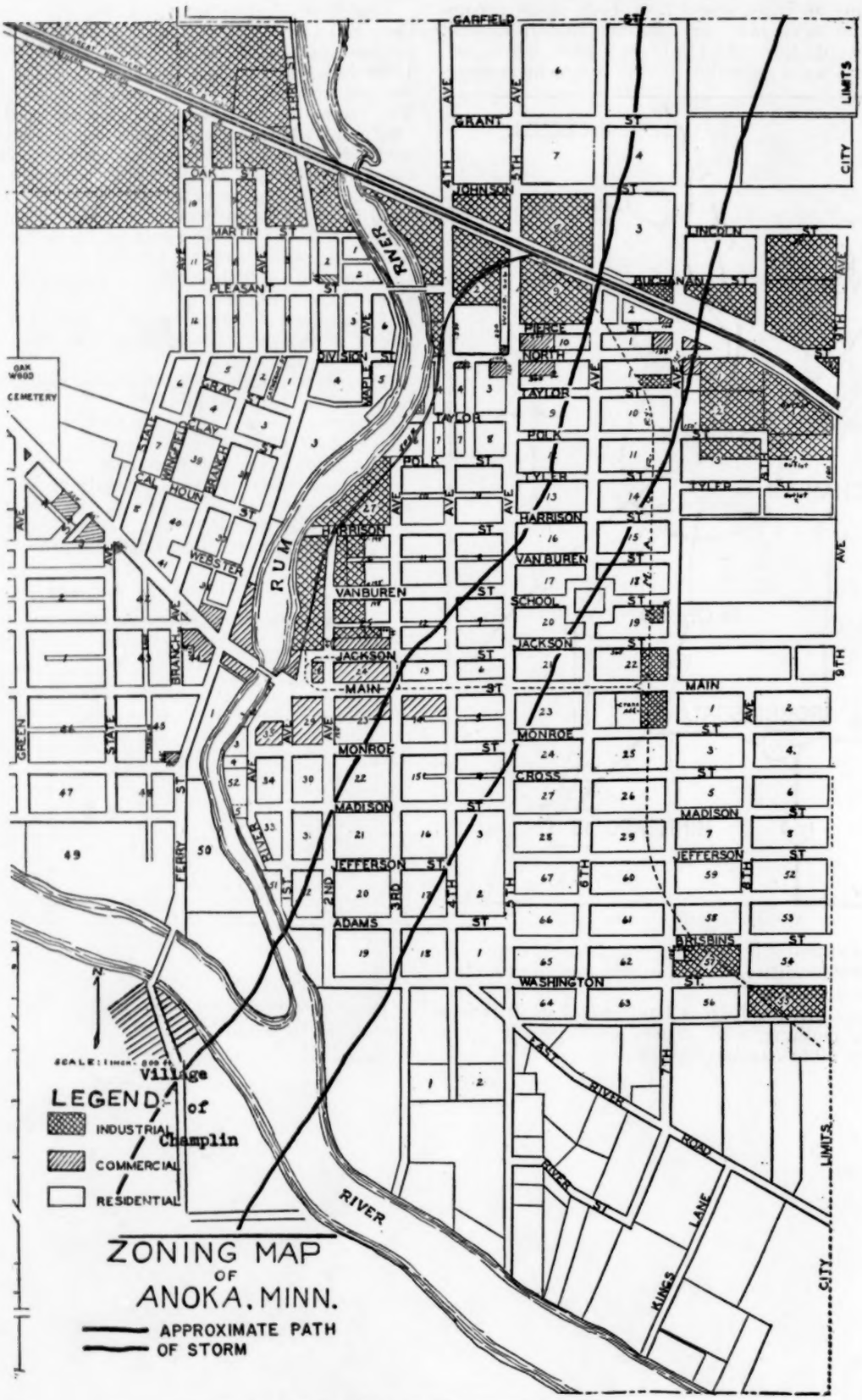

FIGURE 2.—The section of Anoka, Minn., traversed by the tornado.

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By AMY P. LESHER

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Albright, John Grover.

Physical meteorology. New York. 1939. xxvii, 392 p. incl. front., illus., tables, diagrs. 23½ cm. [Prentice-Hall physics series. E. V. Condon . . . editor.] "References": p. 379–380; Bibliography: p. 381–382.

Aldredge, Robert Croom.

Weather observers and observations at Charleston, South Carolina, 1670–1871. Thesis. 215 p. plates, diagrs. 28 cm. [Typewritten.]

American national red cross.

Annual convention, summary of proceedings, San Francisco, May 2–5, 1938. [1938]. 125 p. 23 cm. (Address by Mr. Walter J. Moxom, p. 51–56.)

Baker, Robert Horace.

Astronomy; a textbook for university and college students. 3d ed. New York. [1938]. x, 527 p. incl. front., illus., diagrs. 23½ cm. ("References" at end of most of the chapters.)

Bilham, Ernest George.

The climate of the British isles; being an introductory study of the official records, for students and general readers. London. 1938. xix, 347 p. incl. illus., tables, diagrs. 2 pl., fold. chart. 22½ cm. (Bibliography at end of each chapter except the second.)

Blair, William R.

Some relationships between radio and meteorology. Notes on a lecture delivered April 7, 1937, at New York university. Oceanport, N. J. 1937. 10 p. 27 cm. (War dept. Signal corps laboratories, Fort Monmouth, N. J.)

Brunt, David.

Physical and dynamical meteorology. [2d ed.] Cambridge. 1939. 428 p. illus., maps, tables, diagrs. 27 cm.

Castellani, Sir Aldo.

Climate and acclimatization; some notes and observations. London. 1938. [2d ed.] 198 p. illus., plates, maps, tabs. 19 cm.

China. Huai river commission. Bureau of engineering.

Projects of the flood control, navigation and irrigation for the Huai river system. Huaiyin, China, 1930. vi, 88 p. vi, 134 p. 2, ii p. incl. tables, diagrs., etc. 26½ cm. Chinese and English. "Geographical names in Chinese and English": p. 121–125.

Comité consultatif international des radiocommunications.

Documents. Quatrième réunion. Bucarest, mai/juin 1937. Tome I. Questions à l'étude, Propositions. Tome II. Procès-verbaux et rapports, Avis émis, Questions à l'étude (questions non résolues et questions nouvelles.) Berne. 1937. 2 v. illus., maps, tables, diagrs. 32 cm.

Denucé, Jean.

Les expéditions polaires depuis 1800. Liste des états-majors nautiques et scientifiques. Anvers. 1911. 160 p. 25 cm.

Díaz, Emilio L.

[Meteorological papers.] Buenos Aires. 1936–1937. v. p. illus., maps, tables, diagrs. 27 cm.

Cartas de vientos superiores. p. 585–588. [From Boletín del Centro naval, año 55, núm. 520. Septiembre y octubre, 1936.]

Notas sobre la radiación solar y la circulación atmosférica en territorio Argentino. p. 36–38. [De los "Anales de la Sociedad Científica Argentina." Enero de 1937. E. I, T. CXXIII.]

Díaz, Emilio L.—Continued.

Los pronósticos y sus realizaciones, abril a noviembre de 1936. Guadalajara, Mexico. 1937. 16 p. 2 fold. pl. (maps).

Las situaciónes isobáricas y los vientos superiores. p. 199–202. [From Boletin del Centro naval, año 55, núm. 519. Julio y agosto, 1936.]

Sobre efectos de la radiación solar en la estratosfera. p. 270–274. [De los "Anales de la Sociedad Científica Argentina." Octubre de 1937, E. IV, T. CXXIV.]

Sobre la correlación entre la radiación solar y la presión en Valdivia (Chile). p. 395–397. [De los "Anales de la Sociedad Científica Argentina." Octubre de 1933. E. IV, T. CXXII.]

Velocidad del viento en Cristo "Redentor" y la radiación solar. p. 248–250. [De los "Anales de la Sociedad Científica Argentina." Octubre de 1936. E. IV, T. CXXII.]

Foley, Arthur Lee.

College physics. 2d ed. Philadelphia. [©1937]. xii, 777 p. col. front., illus., diagrs. 22 cm.

Garnett, Alice.

Insolation and relief, their bearing on the human geography of Alpine regions. With maps and diagrams specially prepared by the author. London. 1937. xvi, 71 p. incl. illus. (maps, etc.), tables, diagrs. 24½ cm. (The Institute of British geographers. Publication no. 5.) Bibliographical footnotes.

Hungary. Königlich ungarische Universität in Debrecen. Geographische Institut.

Witterungsbericht. 1929–1931. 1933. [Debrecen. 1929–1933.] 4 v. 30 cm. (1933 incomplete.)

Hungary. Tiszántuler Landwirtschaftskammer.

Witterungsbericht des agrometeorologischen Beobachtungsnetzes. 1929–1931. 30 cm. (1931 incomplete.)

Loewy, Adolf, & Wittkower, E.

The pathology of high altitude climate, with contributions to the climatology of highland regions and to the constitution of high-altitude inhabitants. London. 1937. ix, 212 p. tables (1 fold.) 22½ cm. (Oxford medical publications.) "Literature" at end of most chapters.

Lugeon, Jean, & others.

Résultats des observations de l'éxpedition polonaise de l'anneé polaire 1932/1933 à l'Île des Ours. Fasc. I, Météorologie; Fasc. II, Magnétisme terrestre; Fasc. III, Parasites atmosphériques; Fasc. IV, Aurores polaires. Jean Lugeon, Czeslaw Centikiewicz, Wladyslaw Lysakowski. Warsaw. 1936. 4 v. illus., plates, maps, tables, diagrs. 31½ cm. (Institut national météorologique de Pologne.)

Martinique. [Service météorologique.]

Le Service météorlogique et de physique du globe de la Martinique (Antilles françaises). Paris. [1937.] 44 p. illus., map. 25 cm.

Meigs, Peveril.

Climates of California. [Sacramento. 1938.] iii, 44 p. incl. illus., etc., 23 cm. ([California. Committee on science guide for elementary schools.] Science guide for elementary schools, vol. v, no. 1.) Bibliography: p. 42–44.

Milne-Thomson, Louis Melville.

Theoretical hydrodynamics. London. 1938. xxi, 552 p. illus., 4 pl. 25½ cm. "Errata" slip inserted.

Moese, O., & Meier, P.

Meteorologische Beobachtungen und Reiseberichte der Islandfahrten des Vermessungsschiffes "Meteor" im Rahmen des zweiten Internationalen Polarjahres 1932–1933. Berlin. 1936. 40 p. maps, tables, diagrs. 23 cm. (Veröffentlichungen des Marine-Observatoriums in Wilhelmshaven. Neue Folge, Heft 4.)

168460—39—2

Morin, H. G. S., & Carton, P.

Contribution à l'étude de l'influence des facteurs climatiques sur la répartition de l'endémie palustre en Indochine. [193–.] p. 459–480. (At head of title: Renseignements techniques d'Indochine.) [Service antipaludique des Instituts Pasteur et Service météorologique de l'Indochine.]

Nicholson, Arnold.

Wanderers in the sky. [Philadelphia. 1938.] [16] p. illus. 21½ cm. [Reprint from Country gentleman. August, 1938.]

Paulcke, Wilhelm.

Praktische Schnee- und Lawinenkunde. Berlin. 1938. 217 p. illus., tables, diagrs. 19 cm. (Verständliche Wissenschaft, Bd. 38.)

Pers, Robert.

Recherches sur les durées d'insolation. Grenoble. 1937. 163 p. illus., plates, tables, diagrs. 25½ cm.

Rouch, J.

Leçon d'ouverture du cours d'océanographie physique. Monaco. 1938. 22 p. illus., diagr. 25½ cm. (Bulletin de l'Institut océanographique. No. 749. 10 mai 1938.)

Rouse, Hunter.

Fluid mechanics for hydraulic engineers. 1st ed. New York & London. 1938. xvi, 422 p. incl. front., illus., diagrs. 23½ cm. (Engineering societies monographs; H. W. Craver, consulting editor.)

Schardin, Hubert.

Das Toeplersche Schlierenverfahren. Grundlagen für seine Anwendung und quantitative Auswertung. Berlin. 1934. 32 p. illus., tables, diagrs. (Forschungsheft 367. Beilage zu "Forschung auf dem Gebiete des Ingenieurwesens," Ausgabe B, Bd. 5, Juli/August 1934.)

Schultz-Medow, Max.

Der Fluglehrer; seine Eigenschaften und Aufgaben. Hamburg. 1936. 39 p. 21 cm.

Schulze, Alfred.

Die Niederschlagsverhältnisse der ostdeutschen Provinzen unter besonderer Berücksichtigung ihrer Veränderlichkeit. Breslau. 1936. 96 p. tables, diagr. 24½ cm. (Veröffentlichungen der Schlesischen Gesellschaft fur Erdkunde E. V., und des Geographischen Instituts der Universität Breslau. 22. Heft.)

Shaw, Sir William Napier.

The drama of weather. [2d ed.] Cambridge. 1939. 307 p. illus., maps, tables, diagrs. 21 cm.

Spain. Servicio meteorológico.

Instrucciones para las observaciones meterológicas a bordo y claves de meteorogramas. Madrid. 1935. 87 p. illus., plates, tables, diagrs. 24½ cm. (Publicación serie C, núm. 6.)

Uhlisch, Heinz.

Untersuchungen über hohe Januar-Mitteltemperaturen in Norddeutschland. Inaugural-Dissertation. Berlin. 1936. 35 p. plates, tables. 21½ cm.

Wead, Frank Wilber.

Gales, ice and men; a biography of the steam barkentine *Bear*. Decorations by Charles E. Pont. New York. 1937. xii, 272 p. col. front., plates (1 fold.) 22 cm. Head & tail pieces.

Willett, Hurd C.

The importance of observations from the upper atmosphere in long-range weather forecasting. [New York. 1937.] p. 807–814. 27 cm. (From Journal of applied physics. v. 8, no. 12. December, 1937.)

Woodman, J. Edmund.

The New York university Institute of aeronautical meteorology, its structure and problems. New York. 1935. 7 p. plates. 27½ cm. (Contributions from the Aeronautical meteorological laboratories of New York university. No. 6. December, 1935.) [Mimeographed.]

Wright, William Bourke.

The Quaternary ice age. London. 1937. xxv, 478 p. illus., 23 pl. (incl. front., maps (1 fold.)), diagrs. 22½ cm. First edition 1914. Second edition 1936. Includes bibliographies.

Zehnder, Louis.

L'influence de l'éther sur le temps. Neuchâtel, Switzerland. 1929. p. 101–110. 28 cm. (*In* Annales de l'Institut de géophysique & sciences diverses, Fondation Guébhard-Séverine. 5me année, 1929.)

SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

SOLAR RADIATION OBSERVATIONS, JUNE 1939

By IRVING F. HAND

Measurements of solar radiant energy received at the surface of the earth are made at eight stations maintained by the Weather Bureau, and at nine cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory of Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.

The geographic coordinates of the stations, and descriptions of the instrumental equipment, station exposures, and methods of observation, together with summaries of the data, obtained up to the end of 1936, will be found in the MONTHLY WEATHER REVIEW, December 1937, 65: 415 to 441; further descriptions of instruments and methods are given in Weather Bureau Circular Q.

Table 1 contains the measurements of the intensity of direct solar radiation at normal incidence, with means and their departures from normal (means based on less than 3 values are in parentheses.) At Lincoln the observations are made with the Marvin pyrheliometer; at Washington, Madison, and Blue Hill they are obtained with a recording thermopile, checked by a Marvin pyrheliometer at Washington and with a Smithsonian pyrheliometer at Blue Hill. The table also gives vapor pressures at 8 a. m. (seventy-fifth meridian time) and at noon (local mean solar time).

Table 2 contains the average amounts of radiation received daily on a horizontal surface from both sun and sky during each week, their departures from normal and the accumulated departures since the beginning of the year The values at most of the stations are obtained from the records of the Eppley pyrheliometer recording on either a microammeter or a potentiometer.

Direct radiation averaged close to normal for June at Madison, Lincoln, and Blue Hill, and above normal at Washington.

Total solar and sky radiation was above normal at all stations with the exception of New Orleans and Friday Harbor.

Polarization observations made at Madison on 5 days give a mean of 60 percent with a maximum of 65 percent on the 3d. Both of these values are close to the corresponding June normals.

TABLE 1.—*Solar radiation intensities during June, 1939*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 5	10.59	0.69	0.81	0.93	1.11	1.33					7.87
June 6	13.13	.64	.75	.87	1.01	1.31					11.81
June 9	16.79				0.88						16.20
June 12	12.68				.86						12.68
June 15	16.79	.72	.80	.86	.91						13.61
June 16	19.23			.80	.94						17.96
June 21	11.81				1.10						11.81
Means		**.75**	**.79**	**.86**	**.97**	**(1.32)**					
Departures		**+.12**	**+.11**	**+.07**	**+.02**						

MADISON, WIS.

June 3	9.47		1.00	1.19	1.24						8.81
June 5	9.83		0.93	1.06	1.20	1.42					12.24
June 6	14.10		.77	0.96	1.11	1.39					15.65
June 7	17.37		.59	.68	1.18	1.44					19.89
June 13	7.29		.89	1.08	**1.18**						7.87
June 20	15.65		.86	1.01	1.20						13.61
June 24	13.13	0.69	.76	.92	1.13						11.81
June 30	11.81	.64	.75	.88	1.07						10.59
Means		**(.66)**	**.82**	**.97**	**1.16**	**1.42**					
Departures		**−.08**	**−.03**	**0**	**+.10**	**+.09**					

LINCOLN, NEBR.

June 1	13.61				1.01						13.61
June 3	7.87		1.00	1.13	1.30		1.24				8.81
June 5	12.68			1.05	1.24	1.47					15.11
June 6	15.65						0.95	0.75	0.60		16.79

TABLE 1.—*Solar radiation intensities during June, 1939*—Continued

LINCOLN NEBR.—Continued

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 7	16.79							.88	.76		20.57
June 9	13.11						1.17				14.10
June 13	10.21						1.20	.91			10.21
June 16	14.10			0.58	0.87						7.87
June 17	15.11		0.78	.94	1.12	1.40					15.65
June 18	13.61						.86	.67	.57		17.37
June 23	10.97			1.15	1.39						10.21
June 29	14.60			1.03							10.59
June 30	11.81			1.09	1.26	1.48					9.47
Means			**(.89)**	**1.00**	**1.17**	**1.45**	**1.08**	**.80**	**.64**		
Departures			**+.10**	**+.06**	**+.06**	**+.09**	**−.02**	**−.11**	**−.14**		

BLUE HILL, MASS.

June 2	7.9					1.33	1.02	0.82	0.70		8.2
June 3	7.1					1.39	1.11	.99	.86		7.4
June 4	8.6							.86	.61		11.1
June 6	8.2					1.38			.93		5.4
June 11	15.8						0.98	.82			18.2
June 13	9.6				0.87	1.11					11.9
June 15	9.9				1.10	1.29	1.12	.93			8.8
June 18	8.8			1.01	1.16	1.39					7.1
June 19	8.6					1.37					6.5
June 22	7.9			1.02	1.17	1.35	1.04	.90			9.2
June 24	10.3						.98				11.5
June 28	12.8							.48			13.7
Means				**(1.02)**	**1.08**	**1.33**	**1.04**	**.83**	**.78**		
Departures				**+.01**	**+.01**	**+.04**	**−.11**	**−.14**	**−.03**		

* Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
1939	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
June 4	692	518	586	532	510	740	414	645	679	536	403	627	561	578	525		577
June 11	647	584	571	503	565	736	576	601	629	442	457	643	589	672	510		568
June 18	544	529	632	495	478	723	478	700	524	532	474	590	639	653	485		636
June 25	539	571	592	485	444	721	511	638	600	410	374	607	430	721	618		521
DEPARTURES FROM WEEKLY NORMALS																	
June 4	+184	+3	+32	+78	+70	+66	−61	+57	+101	+29	−66	+71	+34	−6	−97		+1
June 11	+143	+74	+21	+50	+115	+30	+72	−17	+43	−38	−30	+41	+67	+112	−8		+42
June 18	+50	−2	+47	+22	+42	−1	−37	+24	−41	+79	+4	−12	+88	+101	−97		+112
June 25	+17	+38	−8	+40	+6	+2	+44	+2	+36	−69	−66	+12	−63	+166	+36		+14
ACCUMULATED DEPARTURES ON JULY 1																	
	+8,673	+5,460	−3,255	+8,518	+3,206	−98	−469	+343	+3,311	+903	+3,703	−1,057	+42	+4,800	+3,745		−364

POSITIONS AND AREAS OF SUNSPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.) Superintendent, U. S. Naval Observatory. Data from measurements at the U. S. Naval Observatory from plates obtained at the observatories indicated. Difference in longitude is measured from the central meridian, positive toward the west. Latitude is positive toward the north. Areas are corrected for foreshortening and expressed in millionths of Sun's visible hemisphere. For each day, below longitude, latitude, area of spot or groups, and spot count, are given respectively the assumed longitude of the center of the disk, assumed latitude of the center of the disk, total area of spots and groups, and total spot count]

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
June 1	13 27	6470	−38	77	−21	43	388	33	VG	U. S. Naval.
		6471	−35	80	+12	36	242	5		
		6471	−30	85	+11	32	24	9		
		6469	−23	92	−8	25	97	16		
		6466	−20	95	+9	22	73	25		
		6473	−19	96	−12	21	73	10		
		6468	−18	97	−18	25	36	5		
		6475	−9	106	−5	10	12	6		
		6465	−8	107	+6	11	388	40		
		6464	0	115	+23	24	6	5		
		6464	+4	119	+23	24	6	8		
		6474	+10	125	+15	18	6	3		
		6463	+12	127	−16	19	24	6		
		6457	+45	160	+20	49	97	10		
		6456	+50	165	−20	53	121	8		
		6456	+59	174	−20	61	145	7		
		6452	+69	184	+29	72	121	10		
		6452	+78	193	+24	79	145	4		
				(115)	(−1)		2,004	210		
June 2	9 37	6477	−84	20	+8	84	48	1	F	Mount Wilson.
		6470	−26	78	−22	33	364	15		
		6471	−25	79	+13	29	242	8		
		6469	−10	94	−8	13	145	4		
		6466	−10	94	+8	14	73	11		
		6473	−7	97	−12	13	73	3		
		6476	−4	100	+11	13	73	2		
		6465	+3	107	+7	8	388	12		
		6464	+11	115	+21	24	12	2		
		6474	+21	125	+16	27	12	1		
		6457	+58	162	+22	62	145	6		
		6456	+65	169	−19	66	145	5		
		6452	+80	184	+26	81	121	1		
				(104)	(−1)		1,841	71		
June 3	10 52	6478	−77	13	−13	79	6	1	P	Do.
		6477	−73	17	+9	74	97	2		
		6470	−13	77	−22	25	194	10		
		6471	−12	78	+14	18	267	10		
		6466	+3	93	+7	8	194	12		
		6469	+3	93	−8	9	109	2		
		6468	+5	95	−19	19	12	1		
		6473	+10	100	−11	15	24	1		
		6476	+10	100	+13	17	73	4		
		6465	+17	107	+7	18	339	15		
		6457	+73	163	+21	74	194	3		
				(90)	(0)		1,509	61		
June 4	10 43	6480	−75	2	+11	75	97	3	P	Do.
		6479	−68	9	+7	69	242	4		
		6477	−54	23	+8	55	73	6		
		6471	+3	80	+13	14	242	4		
		6470	+3	80	−22	22	194	4		
		6466	+16	93	+7	18	194	1		
		6476	+19	96	+10	22	97	2		
		6469	+19	96	−8	21	85	1		
		6465	+39	107	+8	31	291	8		
		6457	+85	162	+21	86	97	1		
				(77)	(0)		1,612	34		
June 5	10 59	6481	−70	354	+17	71	73	4	F	U. S. Naval.
		6480	−63	1	+10	64	194	30		
		6479	−57	7	+7	58	242	12		
		6477	−43	21	+8	44	61	9		
		6471	+13	77	+12	18	267	7		
		6470	+17	81	−22	27	97	6		
		6466	+29	93	+6	30	97	10		
		6476	+32	96	+11	34	48	7		
		6469	+32	96	−9	24	48	1		
		6465	+43	107	+6	44	267	13		
				(64)	(0)		1,394	99		
June 6	11 5	6484	−70	340	+7	71	12	2	VG	Do.
		6481	−65	345	+19	67	170	1		
		6481	−58	352	+17	60	170	10		
		6483	−52	358	−22	56	12	1		
		6480	−47	3	+11	48	388	15		
		6479	−44	6	+8	45	48	3		
		6479	−40	10	+5	40	194	2		
		6477	−29	21	+8	30	73	8		
		6482	+13	63	−26	28	48	5		
		6470	+29	79	−22	36	24	3		
		6471	+30	80	+12	33	339	10		
		6466	+37	87	+9	38	61	2		

POSITIONS AND AREAS OF SUNSPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
June 6	11 5	6476	+44	94	+9	35	6	1		
		6469	+44	94	−9	45	73	2		
		6466	+45	95	+6	46	48	8		
		(*)	+52	102	+11	54	6	2		
		6465	+58	108	+6	59	145	2		
				(50)	(0)		1,817	77		
June 7	11 25	6481	−51	346	+19	54	97	1	F	U. S. Naval.
		6481	−46	351	+17	49	194	14		
		6480	−35	2	+10	37	339	12		
		6479	−30	7	+8	31	48	6		
		6479	−27	10	+7	28	145	1		
		6477	−15	22	+9	18	36	1		
		6482	+26	63	−26	36	6	4		
		6470	+42	79	−23	47	6	1		
		6471	+42	79	+12	44	242	5		
		6466	+50	87	+10	51	36	1		
		6466	+59	96	+6	60	97	5		
		6465	+70	107	+7	71	145	2		
				(37)	(0)		2,782	53		
June 8	11 24	6485	−78	306	+24	80	339	6	F	Do.
		6481	−38	346	+19	43	48	5		
		6481	−33	351	+17	37	242	11		
		6483	−25	359	−21	33	24	1		
		6480	−21	3	+10	24	194	7		
		6479	−14	10	+7	15	121	3		
		6477	−4	20	+8	10	73	9		
		6471	+54	78	+13	56	170	3		
		6466	+63	87	+10	65	48	1		
		6466	+70	94	+7	71	97	4		
		6469	+73	97	−9	74	24	1		
		6465	+85	109	+7	86	12	1		
				(24)	(0)		1,392	52		
June 9	11 26	6486	−74	296	+3	74	242	3	VG	Do.
		6485	−64	306	+25	68	679	18		
		6481	−19	351	+17	26	339	33		
		6483	−19	351	−21	28	6	3		
		6483	−11	359	−21	24	12	6		
		6480	−8	2	+11	14	73	15		
		6479	0	10	+7	8	97	10		
		6477	+11	21	+8	14	73	10		
		6482	+54	64	−24	59	48	10		
		6471	+70	80	+13	71	194	4		
		6466	+83	93	+6	83	97	3		
				(10)	(0)		1,860	115		
June 10	10 51	6486	−67	291	+3	67	145	6	G	Do.
		6488	−64	294	−16	66	36	3		
		6486	−60	298	+3	60	206	10		
		6487	−55	303	−13	57	12	4		
		6485	−50	308	+24	54	630	40		
		6481	−6	352	+18	18	388	25		
		(*)	+11	9	−8	14	12	3		
		6479	+13	11	+7	15	97	8		
		6477	+25	23	+7	26	24	1		
		6482	+66	64	−24	69	12	5		
		6471	+84	82	+12	84	48	1		
				(358)	(0)		1,610	106		
June 11	12 7	6486	−53	291	+3	53	170	13	VG	Do.
		6488	−51	293	−15	54	36	4		
		6486	−46	298	+3	46	182	3		
		6487	−41	303	−11	43	6	3		
		6485	−37	307	+24	43	436	33		
		6481	+8	352	+18	19	339	25		
		6479	+27	11	+6	27	73	5		
		6489	+27	11	−7	28	48	4		
		6482	+81	65	−24	83	24	1		
				(344)	(+1)		1,314	91		
June 12	11 10	6491	−80	251	−17	82	97	3	VG	Do.
		6486	−39	292	+3	39	145	10		
		6488	−37	294	−15	40	109	10		
		6486	−33	298	+3	33	194	1		
		6487	−27	304	−12	29	12	3		
		6485	−25	306	+23	33	388	27		
		6481	+21	352	+17	26	145	9		
		6479	+40	11	+6	41	61	6		
		6489	+41	12	−7	42	34	2		
		6490	+64	35	−8	66	48	2		
				(331)	(+1)		1,223	73		
June 13	13 16	6492	−84	232	+12	86	242	6	VG	Do.
		6491	−61	255	−18	65	48	14		
		6488	−22	294	−15	27	97	13		
		6486	−19	297	+3	19	242	5		
		6487	−12	304	−12	17	24	2		
		6485	−10	306	−23	25	485	41		
		(*)	+32	348	−22	39	36	2		

POSITIONS AND AREAS OF SUNSPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic				Area of spot or group	Spot count	Plate quality	Observatory
			Difference in longitude	Longitude	Latitude	Distance from center of disk				
1939	h m		°	°	°	°				
June 13	13 16	6481	+36	354	+17	39	24	10		
		6479	+55	11	+6	55	36	3		
		6490	+80	36	−7	81	485	15		
				(316)	(+1)		1,719	111		
June 14	11 37	6495	−78	226	−12	79	194	1	VG	Do.
		6492	−75	229	+12	75	388	10		
		6492	−68	236	+12	69	48	3		
		6491	−47	257	−18	50	97	15		
		6488	−9	295	−14	17	97	10		
		6486	−6	298	+3	70	242	18		
		6485	+4	308	+24	23	485	45		
		6494	+40	344	+24	45	12	1		
		6493	+47	351	−22	51	12	1		
		6481	+50	354	+17	52	36	4		
		6480	+59	3	+10	60	6	1		
		6479	+70	14	+7	70	6	1		
				(304)	(+1)		1,623	110		
June 15	11 22	6495	−64	227	−13	66	194	2	G	Do.
		6492	−61	230	+12	62	533	4		
		6491	−33	258	−18	38	170	11		
		6488	+7	298	−13	15	145	14		
		6486	+7	298	+2	7	170	10		
		6485	+16	307	+24	27	339	30		
		6497	+35	326	−5	36	12	2		
		6496	+45	336	+7	45	6	1		
		6481	+65	356	+16	66	12	1		
				(291)	(+1)		1,581	75		
June 16	11 7	6495	−49	229	−13	50	73	2	VG	Do.
		6492	−48	230	+12	49	436	11		
		6495	−45	233	−13	47	24	4		
		6498	−29	249	−6	30	12	4		
		6491	−20	258	−18	27	121	18		
		6486	+21	299	+3	20	170	15		
		6488	+21	299	−14	25	109	20		
		6485	+29	307	+24	36	109	13		
				(278)	(+1)		1,054	87		
June 17	10 56	6492	−40	225	+12	41	24	3	G	Do.
		6495	−36	229	−13	38	145	1		
		6492	−34	231	+12	35	364	16		
		6491	−7	258	−19	21	48	13		
		6488	+34	299	−14	37	194	9		
		6486	+35	300	+2	35	97	6		
		6485	+45	310	+24	49	97	8		
		6497	+65	330	−5	66	6	2		
				(265)	(+1)		975	58		
June 18	9 25	6492	−25	227	+13	27	242	9	P	Mount Wilson.
		6495	−23	229	−13	27	97	1		
		6491	+6	258	−18	20	97	1		
		6499	+40	292	−14	43	145	12		
		6486	+48	300	+3	48	97	5		
		6488	+51	303	−12	53	121	10		
		6485	+59	311	+25	63	121	7		
		6497	+78	330	−3	78	97	8		
				(252)	(+1)		1,017	53		
June 19	10 55	6501	−58	180	+24	61	24	4	P	Do.
		6500	−52	186	−17	55	24	1		
		6492	−10	228	+13	15	485	12		
		6495	−9	229	−13	17	25	3		
		6491	+19	257	−19	27	36	1		
		6499	+52	290	−14	54	145	4		
		6486	+61	299	+3	61	48	2		
		6488	+65	303	−13	67	97	6		
				(238)	(+1)		884	33		
June 20	11 7	6501	−44	181	+25	8	24	4	VG	U. S. Naval.
		6510	−38	187	−16	42	12	3		
		6502	−20	205	+15	24	36	6		
		6492	+3	228	+13	12	388	30		
		6495	+3	228	−13	15	109	1		
		6491	+30	255	−19	36	12	3		
		6499	+65	290	−14	67	194	11		
		6486	+75	300	+3	76	48	1		
		6488	+78	303	−13	80	145	4		
				(225)	(+2)		968	63		
June 21	10 58	6501	−29	183	+26	37	6	2	VG	Do.
		6502	−7	205	+15	15	12	6		
		6492	+17	229	+13	20	436	50		
		6495	+18	230	−13	23	109	5		
		6504	+36	248	+15	39	36	6		
		6503	+38	250	−16	42	24	12		
		6499	+79	291	−14	80	97	4		
				(212)	(+2)		720	85		
June 22	10 37	6501	−17	182	+25	28	48	7	VG	Do.
		6492	+31	230	+12	33	339	40		
		6495	+31	230	−14	34	73	4		
		6504	+50	249	+15	52	24	8		

POSITIONS AND AREAS OF SUNSPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic				Area of spot or group	Spot count	Plate quality	Observatory
			Difference in longitude	Longitude	Latitude	Distance from center of disk				
1939	h m		°	°	°	°				
June 22	10 37	6503	+51	250	−18	55	194	16		
		6505	+68	267	−8	70	12	2		
				(199)	(+2)		690	77		
June 23	11 11	6507	−80	105	−6	80	97	3	G	U. S. Naval.
		6508	−77	108	+4	77	194	1		
		6517	−73	112	−6	74	97	12		
		6506	+36	221	+17	39	24	7		
		6492	+44	229	+12	45	339	30		
		6495	+45	230	−14	47	73	1		
		6503	+65	250	−18	68	170	5		
				(185)	(+2)		994	59		
June 24	11 4	6509	−77	95	−7	78	194	1	F	Do.
		6507	−67	105	−6	68	121	1		
		6508	−63	109	+5	64	194	3		
		6507	−61	111	−5	62	121	15		
		6506	+52	224	+17	54	18	1		
		6492	+57	229	+13	59	388	17		
		6495	+58	230	−14	60	61	1		
		6503	+78	250	−18	80	48	2		
				(172)	(+2)		1,145	41		
June 25	12 20	6514	−81	77	−22	82	145	7	G	Do.
		6509	−63	95	−7	64	194	1		
		6507	−53	105	−5	54	97	10		
		6508	−48	110	+5	48	194	2		
		6507	−46	112	−5	47	121	12		
		6513	−1	157	+23	21	24	3		
		6512	+25	183	+26	34	24	2		
		6510	+37	195	+19	40	18	4		
		6506	+66	224	+16	68	6	1		
		6495	+70	228	−15	72	97	1		
		6492	+71	229	+12	72	339	18		
				(158)	(+2)		1,259	61		
June 26	11 0	6517	−79	67	−21	81	194	1	G	Do.
		6514	−70	76	−23	73	145	10		
		6509	−50	96	−7	57	194	1		
		6507	−41	105	−6	42	97	4		
		6508	−36	110	+5	36	194	1		
		6507	−31	115	−6	32	97	6		
		6513	+11	157	+23	25	24	6		
		6516	+27	173	+8	27	12	2		
		6515	+40	186	−18	44	48	5		
		6510	+49	195	+19	51	97	8		
		6492	+84	230	+12	85	97	6		
				(146)	(+2)		1,119	50		
June 27	14 47	6520	−80	50	+20	81	36	8	G	Do.
		6517	−64	66	−21	67	242	97		
		6514	−54	76	−23	59	194	4		
		6509	−35	95	−8	36	242	12		
		6508	−31	99	+7	31	61	7		
		6519	−29	101	−13	33	24	4		
		6507	−21	109	−5	22	194	15		
		6508	−20	110	+5	20	194	2		
		6518	−1	129	−15	17	61	5		
		6513	+23	153	+23	30	48	3		
		6516	+44	174	+8	45	97	6		
		6515	+57	187	−18	61	73	4		
		6510	+63	193	+19	66	48	5		
				(130)	(+2)		1,514	172		
June 28	8 48	6522	−81	39	−8	81	218	9	VG	Mount Wilson.
		6520	−70	50	+22	73	36	8		
		6517	−53	67	−21	58	291	7		
		6514	−43	77	−22	49	194	20		
		6509	−24	96	−7	26	194	9		
		6508	−22	98	+7	28	48	6		
		(*)	−22	98	+8	23	12	12		
		6519	−18	102	−14	25	145	50		
		6507	−10	110	−3	12	194	55		
		6521	−10	110	+12	14	12	7		
		6508	−10	110	+6	10	194	8		
		(*)	−6	114	+2	6	24	1		
		6518	+9	129	−13	18	24	8		
		6513	+36	156	+25	42	6	4		
		6516	+56	176	+9	57	170	16		
		6515	+67	187	−16	69	36	3		
		6510	+72	192	+21	75	12	3		
				(120)	(+3)		1,810	226		
June 29	8 35	6522	−65	42	−8	66	242	5	G	Do.
		6520	−56	51	+23	59	24	3		
		6517	−39	68	−21	45	242	4		
		6514	−35	72	−22	42	97	8		
		6514	−25	82	−22	35	97	9		
		6509	−11	96	−7	15	145	18		
		(*)	−9	98	+11	13	12	3		
		6519	−5	102	−13	16	533	60		
		6507	−3	104	−3	6	48	6		
		6521	+2	109	+14	12	12	5		
		6508	+3	110	+5	4	145	9		

POSITIONS AND AREAS OF SUNSPOTS—Continued

Date	Eastern standard time	Mount Wilson group No.	Heliographic: Difference in longitude	Heliographic: Longitude	Heliographic: Latitude	Heliographic: Distance from center of disk	Area of spot or group	Spot count	Plate quality	Observatory
1939	h m		°	°	°	°				
June 29..	8 35	6507	+7	114	−3	9	121	20		
		(*)	+8	115	+25	25	6	2		
		6518	+25	132	−14	29	18	7		
		6516	+67	174	+8	68	121	11		
				(107)	(+3)		1,863	170		
June 30..	11 57	6522	−50	42	−9	51	242	6	F	U. S. Naval.
		6517	−22	70	−22	32	242	2		
		6514	−19	73	−23	32	24	3		
		6514	−10	82	−23	26	61	2		
		6509	+4	96	−7	10	170	21		
		6519	+7	99	−17	20	194	12		
		(*)	+7	99	+9	10	36	8		
		6519	+15	107	−12	20	291	3		
		6508	+19	111	+5	19	170	2		
		6507	+20	112	−3	21	73	11		
		6518	+38	130	−12	40	6	2		
		6516	+81	173	+9	82	12	1		
				(92)	(+3)		1,521	73		

Mean daily area for 30 days, 1,430.

* = Not numbered.
Plate quality: P, poor; F, fair; G, good, VG, very good.

PROVISIONAL SUNSPOT RELATIVE NUMBERS FOR JUNE 1939

[Dependent alone on observations at Zurich]

[Date furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

June 1939	Relative numbers	June 1939	Relative numbers	June 1939	Relative numbers
1	129	11	*Ec* 119	21	68
2	*a* 120	12		22	74
3	*ad* 113	13	*d* ---	23	*dd* 65
4	*a* 97	14	*a* ---	24	74
5	*d* 104	15	*a* 101	25	61
6	124	16	97	26	*c* 84
7	127	17		27	*Ec* 109
8	*d* 113	18	*MWcc* 91	28	*d* 137
9	*ad* 116	19	89	29	*aa* 134
10	*a* 104	20	*aa* ---	30	*a* 118

Mean, 25 days = 102.7

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group through the central meridian.
c = New formation of a group developing into a middle-sized or large center of activity: E. on the eastern part of the sun's disk; W. on the western part; M, in the central-circle zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in charge]

By B. FRANCIS DASHIELL

The 646 upper-air observations of atmospheric pressure, temperature, and humidity made by airplanes and radiosondes in the United States, Canada, Bermuda, the north Atlantic, Canal Zone, and Hawaii, during the month of June 1939, are shown in tables 1 and 1a. The pressures and temperatures, as well as resultant-wind directions and forces, are indicated on charts VIII, IX, X, and XI. Isentropic data for June are shown on chart XII. Tables 2 and 3 present certain upper-air wind observations, and table 4 shows the mean height of the tropopause during the month. A complete description of these charts and tables will be found in the January 1939 issue of the MONTHLY WEATHER REVIEW.

In the lower levels of the atmosphere (up to 5 kilometers) where observations are obtained both by airplanes and radiosonde, all stations but one computed monthly means at 5 kilometers. Of all radiosonde observations launched at the surface 40 percent reached 19 kilometers and 5 stations were able to compute means for 21 kilometers. Individual ascents to 23 kilometers were made at all stations, and one flight over the north Atlantic reached 24 kilometers.

A great area of low mean atmospheric pressure prevailed during June north of the United States across southern Canada and stretched indefinitely northeast of the Hudson Bay region. This pressure distribution is shown on charts VIII, IX, X, and XI. In the United States, however, the lowest mean pressure at the 5,000-foot level (1,524 meters—chart VIII) was recorded on Mount Washington, N. H., while relatively low mean pressures prevailed over the northern Rocky Mountain region. At 3, 4, and 5 kilometers, lowest mean pressures were noted over Spokane, Wash., and highest pressures over the Southeast, particularly Pensacola, Fla., and Norfolk, Va. This distribution varied somewhat from that noted during the preceding spring and winter months when Sault Ste. Marie, Mich., recorded the lowest pressures in the United States.

Above 5 kilometers, where only radiosonde observations are made, lowest mean pressure occurred over Fargo, N. Dak., and highest pressure over Nashville, Tenn., at all levels from 6 to 19 kilometers. Mean pressures at Washington, D. C., and St. George's, Bermuda, were nearly the same for all levels. The latter, however, averaged slightly lower. Over the north Atlantic ocean, between 40° and 43° N. and 47° and 53° W., mean pressures at all levels were slightly higher than those recorded over Halifax, Nova Scotia, but considerably lower than the pressures noted at St. George's, Bermuda.

Charts VIII, IX, X, and XI show the mean temperatures for June at 1.5, 3, 4, and 5 kilometers, respectively. Mean low temperatures occurred over the same areas where lowest mean pressures were noted within the United States. Mean temperatures were highest over El Paso, Tex., at 1.5, 3, and 4 kilometers, and over Pensacola, Fla., at 5 kilometers. San Diego, Calif., was warmer than Pensacola, Fla., at 1.5 and 3 kilometers. At 5 kilometers the lowest mean free-air temperature was —14.4° C. over Spokane, Wash. This was slightly colder than in the preceding month and decidedly lower than in the corresponding month of 1938.

The lowest free-air temperatures for June were recorded over Sault Ste. Marie, Mich., at the surface; over Seattle, Wash., from 0.5 to 2.5 kilometers; Spokane, Wash., at 3, 4, and 5 kilometers; Fargo, N. Dak., from 6 to 12 kilometers; Washington, D. C., at 13 and 14 kilometers; Oklahoma City, Okla., from 15 to 18 kilometers; and over Washington, D. C., at 19 kilometers. The lowest mean temperatures for June were recorded over St. George's, Bermuda, at 12, 13, 14, 15, and 16 kilometers.

While all stations (tables 1 and 1a) were warmer in June than during the preceding month of May in the lower levels, the current month was colder in the higher levels. This was particularly noticeable above the 13-kilometer level over all stations except Fargo, N. Dak.

Above 5 kilometers the lowest mean temperature recorded in the United States during the current month was −67.2° C. over Oklahoma City, Okla., at 16 and 17 kilometers. This was exceeded, however, over St. George's, Bermuda (−68.1° C.) at the same level. Mean temperatures for June were lower at all radiosonde stations than in the preceding months of March, April, and May. The mean of −66.9° C. over Washington, D. C., at 17 kilometers was the lowest recorded since November 1938, and that at Sault Ste. Marie, Mich. (−60.7° C.), has been exceeded but twice—in August 1938 (−61.8° C.) and March 1939 (−60.8° C.). The lowest mean temperature for the current month over Oklahoma City, Okla. (−67.2° C.), was the lowest recorded there since December 1938 (−68.4° C.).

The mean relative humidity in the free air for June was high at most levels, particularly from the surface up to 2.5 kilometers. Pensacola, Fla., and Seattle, Wash., had the highest mean humidity at all levels up to 1.5 kilometers; Norfolk, Va., at 2 and 2.5 kilometers; Billings, Mont., at 3, 4, and 5 kilometers; and Washington, D. C., from 6 to 9 kilometers, inclusive. Humidity was low, however, over San Diego and Oakland, Calif., above 2 kilometers, and over El Paso, Tex., at all levels.

June resultant-wind directions and velocities, computed for 114 stations in the United States, Canada, Mexico, and Cuba, are given on charts VIII, IX, X, and XI (1.5, 3, 4, and 5 kilometers, respectively). Included in the above are data from two new stations—Camden, N. J., and Elkins, W. Va. At the close of the fiscal year the Weather Bureau was conducting regular pilot-balloon observations at 94 stations within the United States (shown on the charts), 1 in Puerto Rico, and 4 in Alaska. A selected list of stations for which resultants have been computed, based on 5 p. m. (E. S. T.) observations, is given in table 2.

Maximum altitudes reached by pilot balloons in the United States during June showed little variation from the previous month. At 33 percent of the stations the maximum altitudes failed to exceed 10 kilometers; 48 percent reached from 10 to 15 kilometers; and only 3 percent passed 20 kilometers. The highest altitude reached was 21,040 meters over Wichita, Kans., but this was exceeded by a flight of 21,186 meters at San Juan, Puerto Rico. During June, however, maximum altitudes obtained at Rapid City, S. Dak., Wichita, Kans., Houston, Tex., Ely, Nev., and Havre, Mont., were considerably greater than those reached in May.

Conditions favorable for long balloon observations at high altitudes existed on June 3d along the Middle Atlantic coast; on the 5th over the Great Lakes and thence southward to Tennessee; on the 8th in Florida; and during the last week of June almost generally elsewhere. An example of the progressive movement of such favorable conditions as noted in the Pacific northwest shows that maximum altitudes were reached on the 27th at Seattle, Wash.; on the 28th at Spokane, Wash.; on the 29th at Missoula, Mont.; and at Billings, Mont., on the 30th. Similar situations elsewhere in the country have been noticed during June and preceding months of this year.

Resultant winds for June, based on 5 a. m. (E. S. T.) observations (charts VIII and IX) showed that the directions at 1.5 and 3 kilometers were from the southwest quadrant in 58 percent of all cases. The 5 p. m. (E. S. T.) resultant directions (charts X and XI) at 4 and 5 kilometers had southwesterly components in 53 percent of all observations. Southwesterly resultants prevailed almost generally at 1.5 kilometers except over New England, New York, Pennsylvania, California, and Canada, where the winds were from the northwest quadrant. In Cuba, southern Florida, Mexico, and on the Gulf coast, the winds were southeasterly. At 3, 4, and 5 kilometers the same situation prevailed except that winds with northwesterly components were noted at points as far south as North Carolina over the extreme East. Winds with northeasterly components occurred over San Antonio, Tex., at 3, 4, and 5 kilometers, and at Jacksonville and Miami, Fla., at 5 kilometers.

Wind directions for June were more southerly in most cases than during the preceding month of May, except in California and a few northern Rocky Mountain stations where the winds were more northerly. Resultant wind velocities during the current month were generally higher than in May. Large increases in velocity over the previous month were noted at Cheyenne, Wyo., Huron, S. Dak., Las Vegas, Nev., Medford, Oreg., Oklahoma City, Okla., Omaha, Nebr., Reno, Nev., and Salt Lake City, Utah. Highest velocities were confined to the northern and eastern sections of the country, as well as to the Rocky Mountain region at 5 kilometers.

Comparing the 5 a. m. (E. S. T.) resultant winds with normals for a limited number of selected stations, it was found that the wind directions at the 1.5- and 3-kilometer levels departed but little from normal. However, large departures in a counterclockwise rotation from normal were noted at Cincinnati, Ohio, Fargo, N. Dak., Key West, Fla., Nashville, Tenn., St. Louis, Mo., Sault Ste. Marie, Mich., and Seattle, Wash. At Key West, Fla., the June directions were 119° and 114°, as compared to the normals of 148° and 170° at 1.5 and 3 kilometers, respectively.

Sault Ste. Marie, Mich., showed the greatest velocity departures from normal—3 meters per second at 1.5 and 3 kilometers. Elsewhere velocity departures from normal were not so pronounced, but in practically all cases the June resultant velocities were slightly higher than the normal at these two levels.

Also comparing the 5 p. m. (E. S. T.) observations at 4 and 5 kilometers (charts X and XI), as well as those at all levels (table 2), with the established 5 a. m. normals, little variation from normal for June was noted. All, however, were more southerly by counterclockwise orientations away from the normal directions. However, at Atlanta, Ga., Cincinnati, O., Houston, Tex., Nashville, Tenn., Omaha, Nebr., and Oklahoma City, Okla., large departures occurred. These also were by counterclockwise rotations away from the normal direction.

Individual maximum velocities for June are shown in table 3. Between the surface and 2.5 kilometers a wind speed of 45.3 meters per second was recorded at Modena, Utah, on the 15th. Between 2.5 and 5 kilometers a velocity of 67.4 m. p. s. occurred on the 3d over Reno, Nev., at 3.9 kilometers. But, above 5 kilometers, at Miami, Fla., a maximum wind speed of 73 meters per second from the North was recorded at 20.6 kilometers on the 8th. This appears to be the first time such a high velocity has been recorded in Florida in the upper air.

MEAN MONTHLY ISENTROPIC CHART [1]

The mean isentropic chart (chart XII) for June 1939, θ=310, is typical of summer charts, with a large anticyclonic tongue extending from the plateau eastward to Toronto, and another tongue extending northeastward along the coast. A third, smaller tongue extends through the central Mississippi Valley.

[1] This chart and the following discussion have been prepared by the Air Mass Section of the Meteorological Research Division.

The departure of precipitation from normal shows only a rough correlation with the moist tongues. Over the western plateau and for some distance eastward there is a general deficit in rainfall which seems to have no relation to the large moist area prevailing over the plateau in summer. The large excesses in precipitation over Oklahoma, Iowa and Minnesota seem to correspond roughly to large up-slope wind components in these regions. The same is true of the excess rainfall in Indiana and Ohio, and on the central Gulf coast. The two large areas of deficient rainfall in the Mississippi Valley and New England correspond to downslope winds.

TABLE 1.—*Mean free-air barometric pressures (P.) in mb., temperatures (T.) in °C., and relative humidities (R. H.) in percent obtained by airplanes during June 1939*

Stations and elevations in meters above sea level	Altitude (meters) m. s. l.																											
	Surface				500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
	Number of observations	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P.	T.	R. H.	P	T.	R. H.	P.	T.	R. H.
Billings Mont. (1,090 m.)	30	890	11.9	77							847	11.4	66	798	8.5	64	751	5.1	68	706	1.9	70	623	−4.7	70	548	−11.4	62
Cheyenne, Wyo. (1,873 m.)	30	811	11.1	61										799	13.6	53	753	11.9	50	708	8.8	49	627	1.4	49	553	−6.6	52
Chicago, Ill. (187 m.)	30	992	18.5	85	955	19.8	71	902	17.7	68	851	14.9	68	802	12.4	62	755	9.9	60	710	7.2	54	628	1.3	48	554	−4.9	42
Coco Solo, C. Z.[1] (15 m.)	29	1,011	25.8	92	957	24.1	91	905	21.9	85	854	19.7	84	806	17.5	80	760	15.7	68	716	13.4	65	635	8.0	65			
El Paso, Tex. (1,193 m.)	30	879	24.0	28							850	25.7	26	802	22.4	26	756	18.8	27	713	14.6	29	632	5.9	34	558	−2.8	46
Lakehurst, N. J.[1] (39 m.)	26	1,012	17.9	81	957	19.5	67	903	17.4	65	852	15.2	69	803	12.7	72	756	10.7	68	712	8.6	59	630	3.2	52	556	−3.0	49
Norfolk, Va.[1] (10 m.)	21	1,016	23.3	91	961	23.4	74	908	21.1	72	856	18.0	79	808	15.1	80	761	12.3	75	717	9.6	65	635	4.4	56	561	−2.1	50
Pearl Harbor, T. H.[1] (6 m.)	30	1,016	22.4	79	960	19.4	80	906	15.6	84	854	12.5	81	804	10.1	74	757	8.9	53	713	6.9	38	630	2.0	24			
Pensacola, Fla.[1] (13 m.)	28	1,015	24.2	94	960	23.9	75	906	21.5	72	856	18.9	67	807	16.4	63	761	13.5	64	717	10.9	60	636	5.6	57	562	0.1	59
St. Thomas, V. I.[2] (8 m.)																												
Salt Lake City, Utah (1,288 m.)	30	868	14.1	58							847	17.3	48	799	15.3	43	753	11.9	44	709	8.1	47	627	0.2	52	553	−7.5	53
San Diego, Calif. (10 m.)	29	1,012	18.0	78	956	14.6	84	902	17.6	63	851	19.1	43	802	17.5	34	756	14.8	31	712	11.5	29	631	5.6	25	558	−1.6	23
Seattle, Wash.[1] (10 m.)	22	1,017	14.8	70	960	10.1	82	904	7.5	82	850	5.4	76	800	2.9	73	751	0.8	65	706	−1.5	56	622	−6.5	46			
Spokane, Wash.[1] (597 m.)	29	944	11.9	71				900	13.3	58	847	10.6	57	798	6.4	62	750	2.3	67	705	−1.6	69	621	−8.2	65	545	−14.4	60

[1] Navy.
[2] Temporarily discontinued.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.
NOTE.—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

TABLE 1a.—*Mean free-air barometric pressures (P) in mb., temperatures (T) in °C., and relative humidities (R H) in percent obtained by radiosondes during June 1939*

Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																			
	Bermuda[1] (50 m.)				Fargo, N. Dak. (274 m.)				Nashville, Tenn. (180 m.)				Oakland, Calif. (2 m.)				Oklahoma City, Okla. (391 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	29	1,012	22.8	85	30	978	13.8	85	30	994	20.8	91	30	1,014	12.1	85	30	966	21.1	84
500	29	961	19.9	88	30	952	16.0	74	30	958	21.4	81	30	956	12.8	76	30	955	21.4	79
1,000	29	907	16.8	88	30	898	14.9	68	30	904	19.5	79	30	901	16.8	50	30	901	21.0	68
1,500	29	855	14.3	82	30	846	12.4	67	30	853	16.5	79	30	849	15.0	41	30	851	18.8	63
2,000	29	806	11.8	78	30	797	9.5	64	30	804	13.8	73	30	800	12.4	36	30	802	16.0	60
2,500	29	759	9.9	73	29	750	6.6	63	30	758	11.1	70	30	754	9.8	33	30	756	13.2	58
3,000	29	714	7.5	67	29	706	3.5	65	30	714	8.8	66	30	709	7.2	30	30	712	9.8	57
4,000	29	632	2.7	61	27	624	−2.3	60	30	632	3.7	62	30	628	1.8	27	29	631	3.3	57
5,000	29	558	−3.0	53	27	549	−8.7	55	29	558	−2.0	59	30	554	−4.5	27	29	557	−3.5	55
6,000	28	491	−9.2	53	27	482	−15.5	52	29	492	−7.4	52	30	487	−11.2	27	29	490	−9.9	51
7,000	28	431	−15.6	47	27	422	−22.5	49	29	432	−13.8	48	30	426	−18.4	27	29	430	−16.1	46
8,000	28	376	−23.0	46	27	367	−30.3	48	29	378	−20.5	45	30	373	−25.4	27	28	376	−23.0	44
9,000	28	327	−31.0	45	26	317	−38.1	48	29	329	−27.9	45	29	324	−32.6	26	28	327	−30.2	42
10,000	28	284	−38.7		26	274	−45.3		29	286	−35.6	44	29	280	−39.8	26	28	284	−37.6	42
11,000	28	244	−46.7		25	236	−50.9		29	247	−43.4		29	242	−46.6		28	244	−45.4	
12,000	28	210	−54.8		24	202	−54.4		29	212	−51.2		29	207	−53.0		28	210	−52.7	
13,000	28	179	−62.1		24	172	−56.9		29	182	−58.0		29	177	−57.1		27	180	−59.0	
14,000	25	152	−65.5		23	147	−58.3		29	155	−62.8		29	151	−60.0		26	153	−63.5	
15,000	24	129	−67.5		20	125	−59.0		29	131	−65.2		29	129	−61.5		26	130	−65.7	
16,000	23	109	−68.1		14	107	−58.8		20	112	−66.1		29	110	−62.6		22	110	−67.2	
17,000	23	93	−66.5		12	91	−59.4		27	94	−66.0		26	93	−63.1		20	93	−67.2	
18,000	17	79	−64.0		9	77	−58.8		24	80	−63.7		25	79	−62.1		17	79	−66.3	
19,000	13	67	−60.8		6	66	−58.4		20	68	−61.1		17	67	−60.6		10	67	−64.4	
20,000	7	57	−57.2						16	58	−57.9		14	57	−58.7		5	57	−62.8	
21,000	5	48	−53.9						11	49	−53.7		7	48	−56.6					
22,000																				

[1] Operated by Massachusetts Institute of Technology.

TABLE 1a.—*Mean free-air barometric pressures (P) in mb., temperatures (T) in °C., and relative humidities (R H) in percent obtained by radiosondes during June 1939*—Continued

(Altitude (meters) m. s. l.	Stations and elevations in meters above sea level																			
	Omaha, Nebr. (300 m.)				Sault Ste. Marie, Mich. (221 m.)				Washington, D. C.[3] (13 m.)				Halifax, N. S.[3] (5 m.)				At Sea[3] (5 m.)			
	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity	Number of observations	Pressure	Temperature	Relative humidity
Surface	30	976	19.2	85	30	987	11.0	89	27	1,015	19.5	86	20	1,015	10.8	.....	26	1,015	13.5	.....
500	30	954	19.9	76	30	955	13.1	80	27	960	19.0	74	20	956	10.9	.....	26	956	13.5	.....
1,000	30	900	18.4	69	30	900	12.3	78	27	906	17.6	69	20	900	9.6	.....	26	901	11.9	.....
1,500	30	849	16.3	63	30	847	10.3	77	27	854	15.0	70	20	847	7.7	.....	26	849	9.9	.....
2,000	30	800	13.4	60	30	798	8.2	73	27	805	12.6	68	20	797	5.7	.....	26	799	7.8	.....
2,500	30	754	10.5	59	30	751	5.6	72	27	758	9.5	65	20	750	3.8	.....	26	752	5.7	.....
3,000	30	710	7.7	55	30	706	3.3	69	27	713	7.1	60	20	705	1.5	.....	26	707	3.4	.....
4,000	28	628	1.9	51	29	624	−2.1	60	27	631	2.1	60	20	622	−3.1	.....	25	624	−1.4	.....
5,000	28	554	−4.2	48	28	549	−8.0	58	27	556	−3.8	62	20	548	−8.5	.....	25	550	−7.2	.....
6,000	28	488	−10.8	46	28	482	−14.4	55	27	490	−9.5	61	20	480	−13.9	.....	25	483	−13.0	.....
7,000	28	428	−17.5	44	28	422	−21.1	52	27	430	−15.1	56	20	420	−19.5	.....	25	423	−19.5	.....
8,000	28	374	−24.7	42	27	368	−28.0	51	27	376	−21.5	57	20	366	−26.0	.....	25	369	−26.7	.....
9,000	28	325	−32.2	40	27	319	−35.7	52	27	327	−29.2	57	20	318	−32.7	.....	24	320	−34.2	.....
10,000	27	282	−39.1	38	27	276	−43.0	.....	27	284	−37.0	.....	19	275	−39.7	.....	24	277	−41.3	.....
11,000	24	243	−46.5	.....	27	238	−49.1	.....	26	246	−44.9	.....	19	237	−46.4	.....	24	239	−47.7	.....
12,000	23	208	−52.5	.....	26	203	−53.5	.....	25	211	−52.7	.....	17	203	−51.3	.....	24	205	−52.8	.....
13,000	22	178	−58.4	.....	25	174	−56.4	.....	25	180	−59.5	.....	16	174	−53.2	.....	24	176	−56.2	.....
14,000	20	152	−61.4	.....	24	149	−57.9	.....	23	153	−64.2	.....	14	149	−55.8	.....	21	150	−57.4	.....
15,000	20	129	−62.6	.....	22	126	−59.4	.....	21	130	−65.6	.....	14	127	−57.6	.....	20	128	−58.6	.....
16,000	20	110	−64.2	.....	19	108	−60.7	.....	17	110	−66.5	.....	12	108	−58.7	.....	16	109	−59.5	.....
17,000	19	93	−65.2	.....	14	92	−59.6	.....	14	93	−66.9	.....	10	91	−58.9	.....	15	92	−59.6	.....
18,000	17	79	−64.3	.....	11	78	−58.0	.....	9	79	−66.0	.....	8	78	−57.6	.....	13	78	−58.4	.....
19,000	14	67	−62.3	.....	5	67	−56.6	.....	8	67	−64.5	.....	6	66	−56.2	.....	12	67	−57.1	.....
20,000	12	56	−60.7	.....	.....	.....	.....	.....	6	57	−62.9	.....	6	56	−55.5	.....	11	57	−55.8	.....
21,000	8	48	−58.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6	48	−54.2	.....
22,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	42	−52.7	.....

[3] Navy.

[3] Soundings made by U. S. Coast Guard Cutters *Champlain* and *Chelan* of International Ice Patrol. The observations at sea were made in an area extending from latitudes 40° to 43° N. and from longitudes 47° to 53° W. Humidity data will be published at a later date.

Observations taken about 4 a. m. 75th meridian time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE—None of the means included in this table are based on less than 15 surface or 5 standard-level observations.

Number of observations refers to pressure only as temperature and humidity data are missing for some observations at certain levels, also, the humidity data are not used in daily observations when the temperature is below −40° C.

TABLE 2.—*Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (E. S. T.) during June 1939*

[Directions given in degrees from North (N=360°, E=90°, S=180°, W=270°)—Velocities in meters per second (superior figures indicate number of observations)]

Altitude (meters) m. s. l.	Abilene, Tex. (537 m.)		Albuquerque, N. Mex. (1,554 m.)		Atlanta, Ga. (302 m.)		Billings, Mont. (1,095 m.)		Boise, Idaho (850 m.)		Brooklyn, N. Y. (15 m.)		Brownsville, Tex. (7 m.)		Buffalo, N. Y. (220 m.)		Burlington, Vt. (132 m.)		Charleston, S. C. (18 m.)		Cheyenne, Wyo. (1,873 m.)		Chicago, Ill. (192 m.)		Cincinnati, Ohio (157 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	154	4.0^{30}	230	3.3^{30}	253	1.0^{30}	5	1.9^{30}	297	2.8^{30}	154	1.3^{30}	148	6.5^{29}	232	2.3^{30}	233	1.0^{28}	173	3.0^{30}	277	2.1^{29}	221	2.2^{30}	211	1.2^{30}
500	.....	.....	.....	.....	240	1.2^{30}	.....	.....	222	3.2^{30}	151	8.0^{29}	235	4.2^{30}	246	2.0^{28}	182	5.5^{30}	.....	.....	.....	.....	221	4.3^{30}	223	2.0^{30}
1,000	158	5.6^{30}	.....	.....	237	2.1^{30}	.....	.....	297	4.1^{30}	274	4.5^{28}	158	7.1^{23}	247	5.4^{30}	252	3.5^{28}	191	4.4^{29}	.....	.....	229	4.3^{28}	226	4.0^{29}
1,500	168	5.5^{30}	.....	.....	243	2.5^{30}	7	1.5^{30}	300	4.1^{30}	285	5.9^{27}	164	5.4^{30}	270	6.6^{28}	247	3.9^{27}	211	3.7^{29}	.....	.....	239	4.2^{28}	244	5.0^{27}
2,000	183	5.3^{30}	235	3.7^{29}	242	3.3^{28}	262	1.3^{29}	302	3.3^{30}	302	6.5^{25}	164	3.9^{17}	285	8.4^{22}	279	4.5^{23}	238	3.3^{25}	288	2.5^{29}	247	4.1^{24}	260	5.4^{22}
2,500	201	3.6^{28}	243	3.9^{30}	239	3.9^{23}	249	4.2^{28}	286	3.6^{28}	303	9.2^{23}	156	3.5^{18}	288	8.7^{19}	309	7.1^{19}	253	3.0^{23}	279	2.7^{29}	258	5.1^{28}	260	6.3^{20}
3,000	223	2.5^{27}	246	5.4^{30}	253	4.4^{23}	254	6.7^{24}	269	5.3^{27}	301	9.9^{19}	148	3.8^{14}	286	9.9^{17}	322	8.1^{28}	259	3.2^{21}	263	4.0^{29}	250	4.4^{17}	257	6.6^{19}
4,000	301	3.1^{23}	253	8.7^{27}	257	4.7^{20}	254	9.6^{19}	262	9.7^{23}	300	11.9^{17}	145	3.8^{11}	302	13.3^{15}	.....	.....	273	3.2^{19}	258	7.2^{29}	.....	.....	269	7.0^{18}
5,000	309	3.1^{23}	259	10.2^{24}	251	5.5^{18}	262	13.0^{19}	253	12.8^{17}	319	12.5^{10}	.....	.....	289	12.2^{10}	.....	.....	276	2.3^{12}	264	12.4^{21}	.....	.....	278	6.0^{10}
6,000	290	4.5^{19}	260	11.6^{23}	255	5.1^{15}	261	14.4^{15}	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	267	18.2^{13}	.....	.....	.....	.....
8,000	289	4.1^{14}	263	16.9^{17}	276	5.4^{12}	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10,000	283	6.2^{13}	275	18.4^{14}	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12,000	.....	.....	282	23.9^{12}	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 2.—*Free-air resultant winds based on pilot-balloon observations made near 5 p. m. (E. S. T.) during June 1939*—Continued

Altitude (meters) m. s. l.	El Paso, Tex. (1,196 m.)		Fargo, N. Dak. (283 m.)		Greensboro, N. C. (271 m.)		Havre, Mont. (766 m.)		Houston, Tex. (21 m.)		Huron, S. Dak. (393 m.)		Las Vegas, Nev. (570 m.)		Little Rock, Ark. (82 m.)		Medford, Oreg. (410 m.)		Miami, Fla. (10 m.)		Minneapolis, Minn. (261 m.)		Nashville, Tenn. (194 m.)		New Orleans, La. (19 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	237	2. 3[20]	253	0. 8[20]	227	0. 8[20]	251	0. 8[20]	162	4. 5[20]	229	1. 9[20]	191	4. 2[20]	170	1. 5[20]	307	3. 5[20]	124	4. 0[20]	218	1. 5[20]	215	1. 6[20]	198	1. 8[20]
500			250	1. 3[20]	246	2. 5[20]			169	6. 5[20]	209	1. 6[20]			185	2. 5[20]	308	3. 6[20]	133	4. 5[20]	207	2. 8[20]	215	3. 0[20]	202	3. 3[20]
1,000			260	2. 5[27]	250	3. 8[20]	261	1. 6[20]	172	5. 4[20]	210	2. 4[20]	201	4. 2[20]	214	3. 4[20]	306	3. 6[20]	132	3. 5[20]	222	3. 8[27]	222	3. 9[20]	204	2. 4[20]
1,500	244	3. 2[20]	249	3. 5[20]	248	5. 1[27]	277	2. 2[20]	186	4. 2[20]	224	3. 5[20]	206	4. 8[20]	236	3. 9[20]	289	3. 1[20]	124	2. 5[20]	232	4. 7[20]	239	4. 2[20]	237	1. 9[27]
2,000	245	3. 2[20]	264	6. 2[24]	260	4. 9[20]	279	3. 4[23]	179	2. 9[20]	242	5. 7[27]	209	4. 8[20]	245	5. 6[20]	270	2. 8[20]	123	2. 1[20]	247	6. 7[20]	254	4. 8[27]	278	0. 7[20]
2,500	255	3. 4[20]	254	8. 4[20]	275	5. 1[20]	263	5. 1[21]	175	3. 2[20]	240	8. 5[23]	222	4. 8[20]	252	6. 4[27]	271	3. 6[20]	126	2. 5[20]	266	8. 0[21]	253	5. 5[20]	281	0. 5[20]
3,000	257	3. 7[20]	257	9. 9[18]	281	5. 9[21]	261	7. 4[19]	180	2. 8[20]	240	9. 9[22]	236	6. 1[20]	258	6. 1[20]	280	4. 8[20]	124	2. 7[20]	266	9. 3[18]	261	4. 7[20]	263	1. 4[20]
4,000	250	5. 4[20]	272	13. 2[24]	281	7. 5[17]	268	10. 0[19]	259	0. 8[19]	242	12. 1[19]	251	8. 5[20]	268	7. 4[20]	280	8. 0[20]	115	3. 2[27]	278	10. 9[19]	261	4. 3[19]	293	1. 0[19]
5,000	256	5. 9[20]	270	14. 6[11]	281	10. 4[11]			285	2. 3[14]	261	14. 3[13]	244	11. 2[20]	263	5. 6[18]	284	10. 1[20]	89	3. 3[20]			246	3. 4[14]	294	2. 3[13]
6,000	257	6. 3[20]	273	17. 4[10]					335	3. 0[10]			248	12. 3[27]	265	6. 4[13]	266	12. 4[19]	87	3. 7[21]						
8,000	262	10. 7[10]											266	14. 2[19]			278	14. 0[17]	76	3. 4[17]						
10,000													265	19. 6[12]			285	16. 7[11]	87	3. 8[13]						
12,000													258	23. 1[10]			282	20. 4[10]								

Altitude (meters) m. s. l.	Oakland, Calif. (8 m.)		Oklahoma City, Okla. (402 m.)		Omaha, Nebr. (306 m.)		Reno, Nev. (1,346 m.)		St. Louis, Mo. (170 m.)		Salt Lake City, Utah (1,294 m.)		San Diego, Calif. (15 m.)		San Juan, P. R. (16 m.)		Sault Ste Marie, Mich. (198 m.)		Seattle, Wash. (14 m.)		Spokane, Wash. (603 m.)		Washington, D. C. (10 m.)		Winslow, Ariz. (1,488 m.)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	270	6. 8[20]	153	5. 7[20]	173	2. 2[20]	258	2. 4[20]	205	1. 6[20]	269	1. 4[20]	263	3. 7[20]	78	7. 6[20]	339	0. 3[20]	229	2. 0[28]	220	3. 0[20]	238	0. 9[20]	248	7. 5[20]
500	274	4. 6[20]	154	5. 7[20]	170	2. 4[20]			216	2. 7[20]			272	2. 7[20]	92	10. 1[20]	321	1. 0[20]	218	2. 0[28]			234	1. 6[20]		
1,000	274	2. 9[20]	177	5. 7[20]	186	3. 3[20]			238	3. 4[20]			278	1. 3[21]	110	8. 6[20]	253	3. 0[21]	223	3. 0[26]	221	4. 0[20]	255	3. 7[21]		
1,500	270	1. 9[20]	192	6. 4[20]	216	4. 0[21]	260	2. 0[20]	245	4. 5[27]	244	1. 5[20]	286	1. 7[21]	114	6. 9[21]	264	5. 4[26]	225	2. 7[22]	234	4. 2[20]	278	4. 8[21]		
2,000	269	1. 3[19]	212	6. 9[26]	236	5. 1[26]	256	2. 6[20]	256	5. 2[27]	238	2. 0[20]	269	2. 7[21]	108	6. 0[26]	274	6. 6[26]	231	2. 1[18]	241	5. 5[20]	285	7. 3[22]	245	5. 1[20]
2,500	270	2. 6[18]	225	6. 5[24]	256	6. 0[24]	261	3. 5[20]	257	5. 5[23]	233	3. 0[22]	249	3. 9[25]	96	5. 5[25]	287	8. 0[22]	233	3. 7[14]	242	5. 9[22]	286	8. 2[19]	245	4. 4[20]
3,000	281	2. 8[24]	251	5. 8[23]	262	6. 1[20]	256	4. 8[20]	270	5. 0[19]	233	4. 4[20]	252	5. 7[21]	94	5. 1[25]	289	8. 6[14]	243	4. 6[14]	239	6. 3[18]	292	9. 3[17]	238	5. 4[20]
4,000	286	3. 6[20]	274	6. 9[19]	272	8. 7[18]	258	7. 2[27]	274	3. 9[12]	245	8. 6[23]	241	9. 1[23]	102	4. 1[24]	293	10. 4[13]	266	7. 5[11]	239	7. 6[10]	312	11. 0[18]	238	8. 1[20]
5,000	291	4. 6[21]	280	7. 8[19]	272	10. 4[17]	278	8. 0[26]			263	9. 1[17]	239	9. 7[24]	100	2. 5[22]							310	12. 1[12]	248	10. 3[20]
6,000	293	6. 3[24]	278	8. 8[17]	270	12. 3[17]	281	9. 7[20]			265	11. 2[18]	254	9. 3[20]	135	1. 4[21]									253	12. 4[21]
8,000	290	8. 0[13]	263	9. 6[13]	259	15. 8[13]	295	14. 1[20]					251	12. 1[11]	333	3. 2[15]									257	16. 3[22]
10,000							292	18. 5[19]							332	4. 3[13]									267	20. 6[19]
12,000																									259	21. 4[13]

TABLE 3.—*Maximum free-air wind velocities (M. P. S.), for different sections of the United States based on pilot balloon observations during June 1939*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m.s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station	Maximum velocity	Direction	Altitude (m.) m. s. l.	Date	Station
Northeast [1]	36. 4	WSW	2, 100	11	Pittsburgh, Pa	38. 1	WNW	4, 420	17	Boston, Mass	43. 6	WNW	5, 920	14	Cleveland, Ohio.
East-Central [2]	36. 4	W	2, 440	23	Nashville, Tenn	35. 6	WNW	4, 500	20	Greensboro, N. C	27. 8	WSW	13, 420	26	Nashville, Tenn.
Southeast [3]	23. 3	SSE	1, 530	13	Tampa, Fla	24. 0	NE	3, 160	14	Mobile, Ala	73. 0	N	20, 620	8	Miami, Fla.
North-Central [4]	33. 8	NNW	2, 150	17	Rapid City, S. Dak	46. 4	WNW	4, 820	4	S. Ste Marie, Mich	50. 2	WNW	10, 780	3	Huron, S. Dak.
Central [5]	37. 0	SW	1, 300	16	Omaha, Nebr	37. 0	SSW	2, 610	16	Moline, Ill	51. 0	SW	10, 280	19	Omaha, Nebr.
South-Central [6]	31. 5	WSW	1, 610	10	Little Rock, Ark	29. 5	NW	5, 000	11	Little Rock, Ark	32. 1	N	13, 510	10	San Antonio, Tex.
Northwest [7]	29. 6	W	870	13	Pendleton, Oreg	36. 4	SSW	5, 000	5	Pocatello, Idaho	46. 8	WSW	7, 300	2	Medford, Oreg.
West-Central [8]	45. 3	SSW	2, 500	15	Modena, Utah	67. 4	SW	3, 960	3	Reno, Nev	64. 2	W	5, 780	26	Ely, Nev.
Southwest [9]	39. 0	NNW	2, 500	1	Sandberg, Calif	40. 0	SW	4, 630	14	Burbank, Calif	58. 0	WNW	10, 680	11	Albuquerque, N. Mex.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and Northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, Southern Ohio, Kentucky, Eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida, and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and Western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, Northern Nevada, and Northern California.
[9] Southern California, Southern Nevada, Arizona, New Mexico, and extreme West Texas.

TABLE 4.—*Mean altitudes and temperatures of significant points identifiable as tropopauses during June 1939, classified according to the potential temperatures (10-degree intervals between 310° and 409° A.) with which they are indentified (based on radiosonde observations)*

Potential temperatures	Fargo, N. Dak.			Nashville, Tenn.			Oakland, Calif.			Oklahoma City, Okla.			Omaha, Nebr.			Sault Ste. Marie, Mich.			St. Georges, Bermuda			Washington, D. C		
	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.	Number of cases	Mean altitude (km.) m.s.l.	Mean temperature °C.
310-319	3	8.9	−48.7				1	7.4	−35.0							4	8.9	−46.5						
320-329	13	10.3	−52.0				3	9.1	−39.7				1	8.7	−32.0	8	9.3	−43.0	1	11.1	−56.0	1	8.7	−32.0
330-339	13	12.7	−55.5	4	11.3	−51.5	12	10.6	−46.3	7	11.8	−56.7	10	10.4	−45.4	12	10.7	−50.3	11	12.7	−56.9	7	11.1	−50.6
340-349	9	12.3	−58.4	24	12.3	−54.4	21	12.3	−56.1	14	12.0	−53.6	15	12.3	−55.2	15	12.0	−55.3	16	12.9	−62.2	9	12.8	−63.1
350-359	3	13.8	−67.7	17	13.5	−61.0	15	13.5	−62.0	15	13.6	−63.1	10	13.2	−59.8	12	13.0	−58.8	13	13.9	−65.9	11	13.5	−62.6
360-369				10	14.8	−64.6	4	13.5	−55.8	8	15.0	−69.9	8	14.0	−58.9	2	13.6	−59.5	6	14.9	−69.3	4	14.4	−63.8
370-379				7	15.0	−64.3	4	14.5	−59.8	8	14.9	−63.8	5	14.5	−62.4	2	13.6	−53.5	5	17.7	−71.6	2	14.8	−63.0
380-389	1	13.9	−52.0	4	15.6	−67.2	4	15.5	−64.2	4	15.9	−67.0	5	15.5	−64.0	2	15.6	−65.5	1	16.0	−70.0			
390-399				6	16.5	−68.2	5	16.0	−65.0	3	16.1	−65.3	4	16.5	−67.8	2	15.4	−60.5	2	16.4	−69.0	3	16.5	−68.7
400-409				1	16.6	−62.0							1	17.1	−68.0							1	16.0	−65.0
All (weighted means)		11.7	−55.3		13.6	−60.1		12.7	−56.2		13.6	−61.5		13.1	−56.8		11.7	−53.3		13.9	−63.9		13.2	−60.4
Mean potential temperature	334.5			354.8			347.8			352.7			350.9			332.4			366.5			354.8		

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

The report for June will be published in the July REVIEW.—*Editor.*

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, I. R. TANNEHILL in Charge]

NORTH ATLANTIC OCEAN, JUNE 1939

By H. C. HUNTER

Atmospheric pressure.—Pressure during June averaged practically normal near the West Indies and the eastern coast of North America, but lower than normal over the central and northwestern portions of the North Atlantic, Bermuda having a deficiency of 0.06 inch. The southeastern portion showed a small excess, and the northeastern a large one, the average of Lerwick, Shetland Islands, being 0.15 inch greater than normal. However, over most of the eastern North Atlantic there was not so great an excess of pressure as during the preceding month.

Over the higher latitudes fluctuations of pressure were both rapid and wide for the time of year.

The extremes of pressure noted in available vessel reports were 30.70 and 29.38 inches. The high mark was recorded during the forenoon of the 21st, on an unidentified vessel near 55° N., 23° W. The low mark was noted within a very few miles of Cape Race, Newfoundland, early on the 1st, by the British liner *Caledonia.*

Table 1 shows that two far northern stations had lower pressure on the 14th than the *Caledonia's* extreme low, while on the 1st the Belle Isle station recorded a pressure of 28.64 inches.

Cyclones and gales.—There were about as many reports of gales along and near the chief routes to northwestern Europe as usual during June. There were several reports of strong gales (force 9), but none of winds of any greater energy. The northwestern portion of the much-traversed area furnished some strong-gale reports for the first week. The morning of the 1st found an intense LOW, which had come from the interior of Canada on an easterly course, centered near the northern tip of Newfoundland; thence it turned toward the north-northeast, so that its influence on transatlantic vessels did not last long. Later cyclones of somewhat less energy caused gales soon afterward in the vicinity of the Grand Banks.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, June 1939.*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.82	−0.04	30.52	23	29.20	14
Reykjavik, Iceland	29.95	+.07	30.71	21	29.26	14
Lerwick, Shetland Islands	29.95	+.15	30.51	1	29.38	28
Valencia, Ireland	30.03	+.03	30.42	9	29.50	28
Lisbon, Portugal	30.06	+.03	30.37	9	29.89	12
Madeira	[1] 30.09	+.02	30.21	7	29.94	25
Horta, Azores	30.20	−.04	30.37	7	29.86	26
Belle Isle, Newfoundland	29.86	.00	30.30	26	28.64	1
Halifax, Nova Scotia	29.98	+.01	30.28	3	29.56	6
Nantucket	29.99	+.01	30.30	3	29.70	6
Hatteras	30.01	.00	30.21	27	29.82	23
Bermuda	30.07	−.06	30.28	13	29.86	23
Turks Island	30.04	+.01	30.12	16	29.91	23
Key West	30.00	+.01	30.14	16	29.85	14
New Orleans	29.98	.00	30.19	21	29.77	14

[1] For 23 days.

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Near the fortieth parallel of latitude, about the 17th to 19th, rather stormy conditions prevailed between longitudes 65° and 35°, where such rough weather is seldom met during the early summer. A LOW of moderate energy, which had come from the Lake region, was central near northeastern Newfoundland on the 17th, with a trough extending far to the southward and southwestward, and this and the moderately high pressure in lower latitudes at the same time were the chief factors in causing the strong winds.

Tropical disturbance.—Elsewhere in this issue of the REVIEW is found an account of the disturbance which affected western Caribbean waters and the central and eastern parts of the Gulf of Mexico about the 12th to 16th. This LOW took in general a northward course and was never of great intensity.

Chart XIII shows the conditions of the 13th, and indicates the path of the center of this disturbance.

Fog.—There was not so much fog as during the preceding May over waters close to the British Isles and France; but from Delaware Bay to the eastern limits of the Grand Banks there was substantially as much as in May, and a decided increase was noted farther northeastward between 45° and 55° N., 20° and 35° W. This last-named region, however, had scarcely any fog close to the middle of the month or during the final week.

The region of the Grand Banks experienced little fog before the 9th, and the waters near the Maritime Provinces and New England had compartaively little during the first 8 days of the month or after the 22d.

There was somewhat less fog than usual during June over waters to southward of Nova Scotia and western Newfoundland, and generally near the 45th parallel from the 30th meridian to the European continent. On the other hand there was more than usual near 50° N., 35° W. As a rule the waters close to the northeastern coast of the United States, and the waters southeast and east of Newfoundland had about as much fog as usual in June.

There were two well-separated 5° squares with 14 days of fog each, the greatest number tabulated from available reports. One was the square from 40° to 45° N., 65° to 70° W., the other from 40° to 45° N., 50° to 55° W.

Two considerable mishaps resulted from fog over Atlantic waters. The British Steamship *Penolver* grounded on the 12th, while approaching Louisburg, Nova Scotia. The vessel was soon freed, but had to be largely unloaded and then docked for repairs. Off Plymouth, England, two vessels collided, probably on the 22d, with much damage to each, but both vessels made port promptly.

OCEAN GALES AND STORMS, JUNE 1939

Vessel	Voyage		Position at time of lowest barometer		Gale began June	Time of lowest barometer, June	Gale ended June	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Leto, Du. S. S.	Rotterdam	Wabana	49 42 N.	39 54 W.	2	Noon, 2	3	29.57	S	SW, 9	W	SW, 9	SW-WSW.
Aztec, Am. M. S.	Tuxpam	Houston	24 30 N.	95 40 W.	3	4a, 3	3	29.87	SE	SE, 5	NW	NW, 8	SE-W-NW.
Chelan, U. S. Coast Guard	On ice patrol out from Halfax.		41 41 N.	53 03 W.	5	3a, 6	5	29.81	SW	NW, 5	S	SW, 9	WNW-N.
Do	do		[1] 41 15 N.	52 07 W.	7	3p, 6	8	29.84	SE	W, 3	SE	S, 8	W-SW.
Black Condor, Am. S. S.	Antwerp	New York	41 10 N.	57 52 W.	5	2a, 7	7	29.59	SSW	SW, 6	N	SSW, 8	SW-NW.
Columbus, Ger. S. S.	Cobh	do	40 42 N.	54 12 W.	7	8a, 7	7	29.63		SE, 8		SE, 8	
Bockenheim, Ger. S. S.	Fredrikshaven	Boston	58 39 N.	15 55 W.	8	Noon, 9	10	29.80	SW	W, 9	W	W, 9	SW-W.
Executive, Am. S. S.	Gibraltar	New York	36 36 N.	60 15 W.	9	1a, 10	10	29.84	SW	SW, 8	SW	SW, 8	SW-NNE.
Hibueras, Am. S. S.	New Orleans	Porto Castilla	21 48 N.	87 00 W.	12	4p, 12	12	29.72		ENE, 6		ENE, 6	ENE-SE.
Oropesa, Br. S. S.	Havana	Cristobal	22 20 N.	84 45 W.	12	2a, 13	13	29.49	S	S, 7	SSE	SSW, 8	S-SSW.
Carrillo, Am. S. S.	Barrios	Charleston	23 00 N.	84 12 W.	12	7a, 13	13	29.69	E	E, 7	SSE	SE, 8	E-SE.
Alabama, Am. S. S.	Houston	San Juan	24 54 N.	85 06 W.	12	3p, 13	14	29.77	E	SE, 8	S	SE, 9	ESE-S.
Orotava, Hond. S. S.	Tela	New Orleans	26 00 N.	88 00 W.	13	4p, 13	13	29.67		NNE, 8		NNE, 8	
Bockenheim, Ger. S. S.	Fredrikshaven	Boston	[1] 51 31 N.	34 03 W.	13	7p, 13	13	29.69	SSW	SW, 9	WSW	SW, 9	SSW-WSW.
Kofresi, Am. S. S.	Tampa	Mobile	29 30 66.	87 36 W.	13	6p, 14	14	29.54	S	NE, 8	NNE	ENE, 8	ENE-N.
Gulfking, Am. S. S.	Portland, Maine.	Port Arthur	26 22 N.	86 15 W.	13	4a, 15	15	29.75	SE	SW, 5	SW	SW, 8	None.
Frode, Dan. S. S.	Aalborg	New York	57 35 N.	20 40 W.	15	11a, 15	15	29.41	W	WSW, 5	W	W, 8	
West Madaket, Am. S. S.	Mobile	London	48 30 N.	18 00 W.	16	4a, 17	18	29.76	W	SW, 8	NNW	SW, 8	
Tuscaloosa City, Am. S. S.	Avonmouth	Baltimore	50 48 N.	17 24 W.	16	5a, 17	17	29.50	W	WSW, 8	W	WSW, 8	SW-WSW.
Chelan, U. S. Coast Guard.	On ice patrol out from Halfax.		41 36 N.	49 00 W.	17	1p, 17	17	29.74	SSW	W, 7	W	SSW, 9	SSW-W.
Excello, Am. S. S.	New York	Casablanca	40 00 N.	63 24 W.	18	8p, 17	18	29.84	NNW	NNE, 4	NNW	NNW, 8	E-NNE.
Spaarndam, Du. S. S.	Antwerp	New Orleans	36 24 N.	53 54 W.	18	7a, 18	18	29.69		SW, 8	SW	SW, 8	W-SW-NW.
Schoharie, Am. S. S.	Bremen	Jacksonville	40 26 N.	38 13W.	19	9a, 19	19	29.88		S, 8		S, 8	
Frode, Dan. S. S.	Aalborg	New York	49 49 N.	39 05 W.	19	4p, 19	19	29.48	S	SW, 8	SW	SW, 8	None.
Exiria, Am. S. S.	Gibraltar	do	40 06 N.	41 36 W.	23	2p, 23	23	29.69	SSW	SW, 8	W	SW, 8	SSW-WSW.
NORTH PACIFIC OCEAN													
Gefion, Nor. M. S.	Yokohama	Estero Bay	43 35 N.	172 24 W.	1	4p, 1	1	29.06	ESE	SE, 8	SE	SE, 8	ESE-SW.
Jefferson Myers, Am. S. S.	Dairen	Portland, Oreg.	48 30 N.	173 00 W.	1	11p, 1	2	29.08	E	E, 10	SE	E, 10	E-ESE.
Manoa, Am. S. S.	Mahukona	San Francisco	37 18 N.	123 24 W.	1	4a, 2	2	29.96	N	NW, 7	NW	NNW, 8	
Toho Maru, Jap. M. S.	Genzan	Los Angeles	45 04 N.	179 57 E.	2	Mdt, 2	2	28.53	SW	WNW, 6	S	SW, 8	NW-SW.
Empress of Russia, Br. S. S.	Victoria, B. C.	Yokohama	50 00 N.	176 00 E.	2	4a, 3	3	29.25	NE	NNE, 11	N	NNE, 11	NE-N.
Kaijo Maru, Jap. M. S.	San Francisco	Niigata	49 56 N.	174 00 E.	2	3a, 3	4	29.33	NE	NNE, 8	NNW	N, 9	N-NNE-N.
Republic, U. S. A. T.	Balboa	San Francisco	15 18 N.	98 00 W.	12	5a, 13	13	29.63	E	E, 8	E	E, 8	
Occidental, Am. S. S.	do	Los Angeles	15 00 N.	96 40 W.	13	2p, 13	13	29.34	E	NNW, 10	W	NW, 10	E-NW.
Pres. Monroe, Am. S. S.	do	do	14 49 N.	96 55W.	13	2p, 13	13	29.10	S	SSE, 6	WNW	NW, 12	SSE-N-NW.
Philadelphia, U. S. N.	do	do	15 03 N.	98 34 W.	13	8a, 13	13	29.44	E	NE, 9	WNW	N, 12	ENE-N.
Dickenson, Am. S. S.	Honolulu	Midway	27 12 N.	173 36 W.	14	6a, 14	14	29.77		S, 9		S, 9	SSE-SW.
Niel Maersk, Dan. M. S.	Yokohama	Los Angeles	45 58 N.	174 41 W.	14	Noon, 15	15	29.59	NNE	ENE, 3	NE	NNE, 9	NE-E.
Lewis Luckenbach, Am. S. S.	Balboa	do	17 18 N.	101 36 W.	27	5a, 28	28	29.72	E	ESE, 7		E, 8	E-ESE.

[1] Position approximate.

NORTH PACIFIC OCEAN, JUNE 1939

By WILLIS E. HURD

Atmospheric pressure.—For the most part the average pressure distribution on the North Pacific Ocean in June 1939 was close to normal. The only radical departure noted was at Petropavlovsk, where the average of 30.01 inches was 0.15 above the normal. The Aleutian LOW was slightly deeper than in the preceding month, owing to the greater and unusual prevalence of cyclones over the central islands of the group, especially during the first and last parts of June. At Dutch Harbor the average pressure was 29.89, as compared with 29.94 in May. High pressure was central over the eastern part of the ocean in middle latitudes. The usual summer LOW prevailed off the China coast.

TABLE 1.—*Averages, departures and extremes of atmospheric pressure at sea level, North Pacific Ocean, June 1939, at selected stations*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	30.06	+0.07	30.44	12	29.76	30
Dutch Harbor	29.89	−.01	30.36	12	29.00	5
St. Paul	29.91	+.05	30.42	13, 14	29.24	5
Kodiak	29.97	+.06	30.40	12	29.72	5, 18
Juneau	30.00	−.01	30.36	10	29.57	14
Tatoosh Island	30.07	+.05	30.29	21	29.56	15
San Francisco	29.94	−.02	30.08	3	29.79	26
Mazatlan	29.84	+.01	29.92	30	29.74	14
Honolulu	30.04	.00	30.13	9	29.95	26
Midway Island	30.07	+.02	30.21	24, 27, 28	29.65	13
Guam	29.86	−.01	29.94	4	29.74	28
Manila	29.80	+.05	29.89	9, 14	29.68	2
Hong Kong	29.70	.00	29.80	4, 5	29.61	19
Naha	29.79	+.04	29.92	4	29.53	16
Titijima	29.86	−.05	30.03	12, 13, 30	29.50	27
Petropavlovsk	30.01	+.15	30.30	15, 23	29.65	30

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales of the extratropics.—By far the most important cyclone of the month was one that left the vicinity of Kamchatka late in May and was centered south of the central Aleutians from the 1st to 3d of June, thereafter moving northward into the Bering Sea with lessened energy. This storm was unusually intense for the latitude in June, with central barometer readings close to 29 inches on the 1st and 3d, and on the 2d falling to 28.53 inches, as reported by the Japanese motorship *Toho Maru*, in 45°04′ N., 179°57′ E. Gales reported in connection with the storm were mostly confined to the area embraced between latitudes 40° and 50° N., longitudes 170° E. and 170° W. Local gales of forces as high as 10 were encountered in the eastern part of the storm region on the 1st, and in the western part on the 2d. The highest wind reported was of force 11, from north-northeast, barometer 29.25, experienced by the British steamship *Empress of Russia*, in 50° N., 176° E., on the morning of the 3d.

During the 13th to 15th a disturbance of locally moderate intensity lay over midocean. On the 13th Midway Island had a barometer of 29.65 inches, and early on the 14th, some 5° to the east-southeastward (in 27°12′ N., 173°36′ W.) the American steamer *Dickenson* encountered a south gale of force 9, barometer 29.77. The disturbance was of great extent, but the only other gales reported in connection with it were experienced by the Danish motorship *Niel Maersk*, maximum force 9, from north-northeast, during the afternoon of the 14th and early on the 15th near 46° N., between 175° W. and 180°.

From the 26th to 30th a disturbance lay over northern waters. Late on the 26th it was central near 45° N., 175° E., but on the 27th and 28th it covered the middle Aleutians, with central pressures close to 29 inches, after which it moved into the southern part of the Bering Sea. Along the northern routes south of the Aleutians, particularly on the 27th, there was some rough weather, with highest wind forces of 7 and 8 reported locally by radio.

Aside from the gales already referred to, only one other was reported from middle or higher latitudes. That was a northerly gale of force 8 experienced by the American steamer *Manoa* on the 1st, while approaching the California coast.

Tropical hurricane off west coast of Mexico, June 13.—A tropical cyclone was reported by several north-bound vessels off the Mexican west coast between the Gulf of Tehuantepec and Acapulco on the 13th. So far as these reports indicate, the cyclone had its origin during the night of the 12th–13th and disappeared from observation before midnight of the 13th. The strongest wind experienced on board the United States Army Transport *Republic* was of force 8 from east, barometer 29.63, at 5 a. m., in 15°18′ N., 98° W. On the American steamship *Occidental*, northwesterly gales of force 10 occurred between about 2 p. m. and 4 p. m., lowest barometer 29.34 at 2 p. m., in 15° N., 96°40′ W.

In a special report prepared by Second Officer H. A. Shutz, of the American steamship *President Monroe*, the ship is indicated as having experienced winds of gale force from shortly after local noon until about 6 p. m., with lowest barometer, 29.10 inches, at 2:20 p. m. The ship's noon position by dead reckoning was 14°49′ N., 96°55′ W. The wind was then south, force 6, barometer 29.82 (corrected); there was heavy rain and a confused sea, with heavy southwest swell. At 1 p. m. the wind had increased to force 10. Now quoting from the report of Mr. Shutz:

1:30, barometer 29.35. At 2 p. m. wind decreased to south-southeast, 6, barometer 29.17; 2:20 p. m., barometer at lowest read 29.10; confused swell and cross seas. 2:30 p. m., wind hauling to north with force of 5. 3 p. m., barometer 29.20, wind north, 10. 3:15 p. m., wind blowing from northwest with full hurricane force, heavy rains, visibility nil; sharp precipitous seas from northwest; short and heavy northwest swell and increasing; wind estimated to be 100 miles per hour. 4 p. m., wind northwest, 12, barometer 29.45, wind slowly shifting to west-northwest, decreasing to force 9. 6 p. m., wind northwest-by-west, force 7.

A further special report of the hurricane was made by the Commander of Cruiser Division Eight, U. S. S. *Philadelphia*, Flagship, and furnished to the Weather Bureau through kindness of the United States Hydrographic Office. This vessel ran into a 30-knot wind from almost due east, at 5 a. m., barometer 29.62, in 14°52′ N., 97°49′ W. At 8 a. m. the ship had lowest barometer, 29.44, accompanied by a northeast gale of force 9, in 15°03′ N., 98°34′ W. At 9:30 a. m., with slowly rising barometer, the wind was highest, of hurricane force, from north-northeast, in 15°09′ N., 98°57′ W.

Tropical disturbance of June 27–28.—On the 27th and 28th the observations of the American steamer *Lewis Luckenbach*, Balboa to Los Angeles, gave suspicion of the formation of a small cyclone up the Mexican coast from Acapulco. The ship was in a moderate east gale at noon of the 27th. At 3 p. m. the force had risen to 8. At 5 a. m. of the 28th the wind was east-southeast 7, diminishing, lowest barometer 29.72, in 17°18′ N., 101°36′ W. There are, however, no further data available concerning this disturbed condition.

Fog.—Over the eastern half of the northern steamship routes fog had increased materially since the preceding month, but over the western half, where fog is usually much more frequently observed than in May, there was little change. The most frequented area in east longitude was between 40° and 45° N., 155° and 160° E., where fog was reported on 6 days. Southwestward, on the route to Yokohama, the intervening 5° squares each had 3 days with fog. In west longitudes fog was observed on 3 to 4 days over most of the area lying between 40° and 50° N., 135° and 175° W. Six days were reported with fog along the Peninsula of Alaska, and 2 off the east China coast. Along the American coast fog was noted as follows: Off Washington on 4 days; Oregon on 1 day; California on 11 days; and Lower California on 4 days.

TROPICAL CYCLONE OF MARCH 1939 IN THE VICINITY OF NEW CALEDONIA AND OVER THE LOYALTY ISLANDS

By WILLIS E. HURD

The Weather Bureau has received, through the United States Hydrographic Office, a report submitted by the commanding officer of the French S. S. *Dumont d'Urville*, a colonial dispatch vessel, on an intense tropical cyclone, which occurred on March 25, 1939, in the vicinity of New Caledonia and later crossed the Loyalty Islands to the eastward going on a southeasterly course.

On March 25 the S. S. *Dumont d'Urville* was anchored in the Bay of Uala, Art Island, north of New Caledonia. In the early morning the wind was light, the barometer was falling, and there were heavy showers. At 9 a. m. the rain became heavier and more continuous, with low visibility. At 11 a. m. the ship's barometer had fallen to 746 mm. (29.37 inches), and the wind, hauling to south of east, was of force 7 to 8. At 12:25 p. m. the barometer had dropped to 736 mm. (28.99 inches), and the wind had risen to force 10–11. At 1:05 p. m., with barometer at 730 mm. (28.74 inches), the wind was of hurricane force, and the ship was dragging anchor. The wind continued at hurricane force until well into the afternoon. The center of the cyclone passed over the ship at 2:30 p. m., accompanied by violent squalls from varying directions, and a low barometer of 711 mm. (27.90 inches). At this time the sky was brightened by a few feeble rays of the sun.

According to the commanding officer, the—

> cyclone probably formed to the northeast of Belep, between Huon and the New Hebrides * * *. It reached the northern part of New Caledonia (Paaba Island) around 1600. It went along the east coast of the island and passed over Ouvea at about 2200, where there were no casualties, but much damage done. A small vessel, *Le Phoque*, at anchor in the lagoon of Ouvea, near Wakat, was blown bodily onto the beach at 0100 on the 26th.
>
> The storm blew itself out on the 27th about 300 or 400 miles southeast of Noumea, between the Fiji Islands and the New Hebrides, after having caused much damage at Mare and at Walpole.
>
> At Mare Island, Loyalty Group, "three missions," according to the report, were demolished, 87,000 coconut trees were lost, and two natives killed.

ADDITIONAL REPORT ON TYPHOONS AND DEPRESSIONS OVER THE FAR EAST, MAY 1939

BERNARD F. DOUCETTE, S. J.
[Weather Bureau, Manila, P. I.]

Typhoon, May 26–31, 1939.—A low pressure area formed over the northern part of the China Sea with a center close to and east of the Paracel Islands and Reefs. As a depression this center moved northwest to a position about 150 miles east of southern Hainan Island where it recurved to the northeast and intensified to typhoon strength (shortly before 6 a. m. May 28). For 1 day it moved along this course to a location about 100 miles west of Pratas where it remained stationary until the morning of May 30, when it weakened as it shifted to a westerly course, thus entering the continent close to and east of Fort Bayard during the forenoon of May 31. No trace of it could be found on the afternoon weather map of that day.

On May 28, while the storm was moving northeast, it intensified to typhoon strength, as is well shown by the observations made on board the S. S. *President Coolidge*. The ship was enroute from Hong Kong to Manila and passed a short distance west of Pratas during the afternoon hours of May 28. During this part of her voyage, a pressure of 29.37 in. (746.0 mm.) was reported with east and east-southeast winds, veering to the southeast, force 8 to 10, accompanied by torrential rain and dense, violent rain squalls. The vessel was at such a distance from the center that the pressure, though low, remained steady throughout the afternoon. May 29, at 6 a. m., from Hong Kong came the report of pressure 750.1 mm. (29.531 in.) with northeast winds force 3. At the same time, Gap Rock reported 749.3 mm. (29.500 in.) and north winds force 6. Ships within 150 miles of the center during the period from May 28 to May 30 had winds of force 3 to 7 and pressure values ranging from 748.5 mm. (29.468 in.) to 750.5 mm. (29.547 in.).

From May 24 to 26, two air streams were converging over the northern part of the China Sea; one from the southwest, flowing over Siam, the southern part of Indochina, the Straits Settlements and the northwestern part of Sumatra. The southwesterly current extended to Manila, where it was overriding the southeasterly current, as shown by the movement of the high clouds and one or two balloon ascents. Only at Bandon was there any sign of strength; there the velocities reached values as high as 50 k. p. h. On May 27, when the depression had definitely formed and was moving, Bandon had velocities up to 80 k. p. h. and Bangkok reported values up to 50 k. p. h. Medan, on Sumatra Island, had velocities as high as 60 k. p. h. This southwesterly current reached Palembang but did not extend any farther to the east over the territory of the Netherland East Indies, The southeasterly current over the Philippines hardly ever reached velocities of 45 k. p. h. at any altitude up to the afternoon of May 26. On May 27, however, Manila and Dagupan had maximum values of 60 and 75 k. p. h., the directions being from the southeast and south quadrants. The highest velocity reported from Guam during these few days was 45 k. p. h., the directions of the air stream there being east and east-southeast.

As the storm moved along its short northeasterly course and intensified to typhoon strength (May 28 and 29) the situation remained practically the same as that of May 27, as far as the available data indicate. It is to be noted that the southwesterly current did not reach Zamboanga, although the surface observations received from the S. S. *Pathfinder*, anchored close to the western coast of northern Palawan, indicate that the ship was under the influence of the southwesterly air stream. When the disturbance began to move westerly toward the continent, diminishing in strength at the same time, the velocities at Bandon still maintained values as high as 50 k. p. h. and the southwesterly air stream extended to Zamboanga, (May 30), and then to Cebu, (May 31). The velocities at Zamboanga and Cebu were not higher than 40 k. p. h. As the depression disappeared over the continent, the southwesterly current extended up to San Bernardino Strait and perhaps a short distance into the Pacific. It also showed its presence aloft over Menado during the last three days of the month. Only a few ascents were received from Tarakan during the course of this storm, and these were almost always identical with those of Zamboanga. A study of the velocities seems to indicate that the activity came from the southwest current. The persistence of velocities of 50 k. p. h. and higher over Siam stations, even after the disturbance had disappeared over the continent, and the extending of the current to Zamboanga and Cebu, even to the locality of San Bernardino Strait, shows the power of that air stream.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, June 1939*

[For description of tables and charts, see REVIEW, January, p. 31]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.1	+0.8	Tuskegee	103	21	Scottsboro	57	12	6.30	+2.10	Florence	12.95	Martin Dam	2.10
Arizona	75.2	−.2	Quartzsite	118	12	Fort Valley	23	18	.04	−.32	Fairbank	.53	68 stations	.00
Arkansas	77.9	+.7	Texarkana	100	[1]8	2 stations	49	11	4.50	+.44	Monticello Airway	10.59	Camden	1.45
California	67.0	−1.1	Greenland Ranch	121	30	Ellery Lake	12	18	.12	−.21	Crescent City (near)	1.83	126 stations	.00
Colorado	62.5	+.8	Lamar	106	14	Fraser	13	19	.82	−.58	Burlington	4.55	7 stations	.00
Florida	80.3	+.5	2 stations	100	[1]22	DeFuniak Springs	58	4	9.23	+2.52	Punta Gorda	20.29	Key West	1.97
Georgia	79.5	+1.4	do	103	[1]20	Blairsville	51	13	4.66	+.24	Bainbridge	13.24	Washington	1.43
Idaho	57.7	−2.6	Orofino	110	29	Pelton's Ranch	16	5	1.29	−.01	Deception Creek	4.06	2 stations	.09
Illinois	73.6	+1.5	Freeport	99	17	Dixon	38	14	5.14	+1.21	Wheaton	10.65	Cairo	2.56
Indiana	73.6	+2.1	2 stations	101	[1]26	3 stations	42	[1]12	6.12	+2.27	Plymouth	10.35	Huntington	2.48
Iowa	71.4	+1.8	3 stations	100	16	2 stations	41	[1]13	5.32	+.70	Lamoni	11.10	Waukon	1.59
Kansas	75.3	+1.5	Johnson	110	14	Atwood	40	11	4.59	+.60	Hutchinson	11.36	Syracuse	.66
Kentucky	75.1	+1.2	Pippapass	97	16	Mammoth Cave	47	5	6.00	+1.48	Richmond	12.90	Paducah (near)	2.43
Louisiana	80.7	+.6	4 stations	100	[1]15	Pollock (near)	60	1	4.42	−.15	Colfax	8.99	Gueydan (near)	1.08
Maryland-Delaware	73.5	+2.7	Dundalk, Md	100	[1]17	Oakland, Md	40	5	4.92	+.88	Oakland, Md	10.96	Snow Hill, Md	1.20
Michigan	65.6	+2.3	Eloise	95	7	2 stations	29	13	4.92	+1.84	Ironwood	11.32	Kalkaska	1.62
Minnesota	65.6	+.7	Wheaton	98	5	Mizpah	33	9	5.15	+1.12	Chaska	9.00	Spring Grove	2.06
Mississippi	79.6	+.7	2 stations	98	[1]17	Corinth	61	9	6.78	+2.57	Pontotoc	12.11	Pelahatchee	2.61
Missouri	74.6	+1.0	3 stations	99	[1]7	Neosho	41	11	5.64	+1.00	Moberly	13.09	Advance	1.15
Montana	55.9	−4.0	Thompson Falls	100	29	2 stations	22	[1]17	3.52	+1.05	Billings No. 2	7.07	Haugan	.99
Nebraska	70.3	+.9	2 stations	105	17	Arthur	35	10	3.84	+.22	Tecumseh	9.78	Hyannis	.99
Nevada	64.9	+.4	Overton	114	[1]28	Sheldon	17	5	.19	−.31	McGill	1.07	19 stations	.00
New England	63.9	−.1	2 stations	94	11	Greenville, Maine	29	2	3.32	−.13	Gilman, Vt	6.51	Barkhamstead, Conn	1.08
New Jersey	70.8	+2.0	Elizabeth	103	9	2 stations	35	7	3.55	−.16	Trenton	6.56	Pleasantville	1.39
New Mexico	69.8	+.9	2 stations	111	[1]13	McGaffey Ranger Station.	19	18	.64	−.62	Solano	4.33	28 stations	.00
New York	66.0	+1.0	Utica	97	12	Lake Placid Club	33	18	3.11	−.54	Gabriels	6.29	Lockport	1.25
North Carolina	77.2	+3.2	Monroe	103	22	Banners Elk	45	[1]24	4.38	−.31	Rock House	9.15	Gastonia	1.65
North Dakota	60.1	−2.4	Lisbon	99	5	Edmore	29	9	4.59	+1.18	McLeod	10.91	Portal	1.90
Ohio	72.5	+3.0	Gallipolis (near)	99	16	2 stations	44	[1]13	6.55	+2.70	Lakeview	14.37	Put-in-Bay	2.65
Oklahoma	78.7	+1.4	Hollis	109	9	Mangum	45	6	5.35	+1.51	Pensacola	10.40	Kenton	.26
Oregon	57.4	−2.2	Umatilla	107	28	3 stations	18	[1]1	1.05	−.20	Headworks	5.87	Fremont	.05
Pennsylvania	69.9	+1.8	Marcus Hook	101	16	Gouldsboro	35	7	4.46	+.33	Uniontown	10.96	Wilkes-Barre (river)	.83
South Carolina	80.6	+3.1	Blackville	107	22	2 stations	59	[1]13	4.08	−.66	Ferguson	8.18	Greenwood	.86
South Dakota	66.3	−.1	Cottonwood	104	5	Cottonwood	33	12	4.15	+.77	Sisseton	9.08	Cottonwood	1.34
Tennessee	76.3	+1.6	2 stations	97	[1]7	Rugby	52	12	5.99	+1.77	Lewisburg	13.43	Tri-City Airport	1.70
Texas	81.4	+1.2	Presidio	113	13	Muleshoe	43	5	3.05	+.09	Huntsville	11.98	2 stations	T
Utah	64.1	−.5	St. George	106	[1]12	2 stations	20	[1]18	.65	+.08	High Line City Creek.	4.07	10 stations	.00
Virginia	74.8	+3.1	Culpeper	100	8	Burkes Garden	44	25	4.50	+.31	Winchester	9.11	Christchurch	1.03
Washington	58.7	−2.0	3 stations	105	[1]28	4 stations	25	[1]1	1.64	+.43	Camp Eight	7.94	Hanford	.07
West Virginia	72.7	+3.0	Hinton	101	16	Bayard	33	5	6.23	+1.82	Morgantown	13.36	Wayne	2.24
Wisconsin	66.3	+1.2	Brodhead	98	16	Coddington	34	12	5.41	+1.37	Park Falls	12.59	Racine	1.84
Wyoming	56.5	−2.2	Torrington	103	5	4 stations	20	[1]4	1.70	+.08	Recluse (near)	4.38	Rawlins	.11
Alaska (May)	40.8	−.5	Livengood	76	[1]23	Pilgrim Springs	−8	14	1.83	+.23	Ketchikan	11.11	2 stations	T
Hawaii	72.5	−.8	2 stations	90	[1]27	Kanalohuluhulu	44	1	5.55	+.82	Kukui (Maui)	36.00	4 stations	.00
Puerto Rico	77.6	−.6	Utuado	95	26	2 stations	57	[1]2	4.08	−2.01	Dos Bocas	14.98	2 stations	.00

[1] Other dates also.

CLIMATOLOGICAL TABLES

TABLE 2.—*Climatological data for Weather Bureau Stations, June 1939*

[Compiled by Annie E. Small, by official authority U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In*
New England							63.6	+0.1										74	3.08	+0.1										5.5		
Eastport	75	67	85	29.88	29.96	+0.03	55.4	+0.3	83	21	64	42	5	47	29	50	46	77	2.19	−0.8	8	9.5	sw.	26	e.	25	7	8	15	6.2	0 0	0.0
Greenville, Maine	1,069	4	41																											.0	.0
Portland, Maine	103	82	117	29.85	29.98	+.03	61.1	−1.4	86	21	69	46	3	54	29	55	50	73	2.08	−1.2	8	8.1	sw.	25	n.	6	12	9	9	4.9	.0	.0
Concord	288	54	72	29.67	29.98	+.02	65.2	+2.3	88	11	77	42	3	53	36				3.61	+.4	11	5.5	se.	19	nw.	16	12	11	7	4.9	.0	.0
Burlington	403	11	48	29.52	29.95	−.01	63.4	−2.3	87	11	73	42	7	54	32	58	53	71	5.35	+2.0	12	8.3	s.	26	s.		8	8	14	6.0	.0	.0
Northfield	876	12	60	29.03	29.96	.00	61.3	.0	87	11	74	35	18	48	38	57	52	71	3.57	+.4	11	6.7	sw.	23	s.	11	7	14	9	5.8	.0	.0
Boston[1]	29	33	62	29.94	29.96	.00	65.6	−.9	88	21	73	52	18	58	25	59	53	68	2.70	−.2	10	11.0	e.	28	s.	30	6	14	10	6.0	.0	.0
Nantucket	12	14	90	29.97	29.99	+.01	61.5	+.5	79	16	68	47	3	55	22	58	55	83	2.94	+.3	8	13.1	s.	34	ne.	6	11	7	12	5.7	.0	.0
Block Island	26	11	46	29.96	29.98	+.01	62.9	+1.1	83	21	70	50	2	56	21	59	56	82	2.66	.0	7	12.5	s.	26	s.	30	14	8	8	4.5	.0	.0
Providence	160	215	251	29.81	29.98	+.01	66.6	−1.7	88	21	76	49	3	58	26	59	54	68	2.70	.0	9	10.5	s.	33	nw.	16	12	11	7	4.8	.0	.0
Hartford	159	62	100				68.6	+1.5	90	9	79	48	18	58	32				3.21	+.1	11	8.0	s.	27	n.	6	9	9	12	6.1	.0	.0
New Haven	106	74	153	29.87	29.98	+.01	68.0	+1.4	86	21	76	51	7	60	28	62	57	71	2.86	−.2	9	8.6	s.	29	n.	6	7	12	11	5.7	.0	.0
Middle Atlantic States							72.6	+2.3										70	3.88	+0.2										6.0		
Albany[1]	292	26	40	29.64	29.96	−.01	67.2	−.8	91	8	79	41	7	55	44	51	54	65	3.04	−.3	11	9.3	s.	30	ne.	6	5	14	11	6.2	.0	.0
Binghamton	871	57	79	29.07	29.98	+.01	67.8	+2.2	91	11	79	42	7	56	40	60	55	67	1.82	−1.6	12	6.1	nw.	17	w.	24	4	11	15	6.9	.0	.0
New York	314	415	454	29.64	29.97	−.01	70.8	+2.0	89	9	79	57	7	63	28	62	56	65	3.98	+.6	11	12.8	se.	43	nw.	6	7	14	9	5.8	.0	.0
Harrisburg[1]	351	30	49	29.61	29.98	−.01	72.5	+2.2	98	17	83	52	15	62	32	64	59	66	2.44	−1.2	13	7.6	w.	34	sw.	11	4	13	13	6.8	.0	.0
Philadelphia	114	174	367	29.86	29.98	.00	73.2	+1.8	95	17	82	55	1	64	34	65	60	67	4.45	+1.2	15	11.8	e.	31	n.	17	8	10	12	5.8	.0	.0
Reading	323	283	306	29.64	29.98		71.5	+1.7	96	17	81	53	7	62	34	63	58	67	4.38	+.8	12	10.3	se.	44	e.	17	6	13	11	6.2	.0	.0
Scranton	805	72	104	29.13	29.98	.00	69.2	+1.4	92	11	80	47	7	59	34	60	55	63	1.29	−2.4	12	6.4	sw.	25	nw.	6	6	14	10	5.8	.0	.0
Atlantic City	52	37	172	29.93	29.98	.00	69.9	+3.3	95	17	76	54	7	63	34	64	61	78	1.60	−1.4	9	14.6	s.	34	s.	11	9	7	14	6.1	.0	.0
Sandy Hook	22	10	57	29.95	29.98		70.4	+2.6	90	9	77	57	7	64	28	64	60	74	2.62	−1.2	8	11.2	s.	32	s.	13	7	12	11	5.8	.0	.0
Trenton	190	86	107	29.78	29.98		71.8	+2.3	96	17	81	54	7	62	35	64	59	68	6.56	+3.5	10	8.3	s.	26	nw.	6	4	13	13	6.3	.0	.0
Baltimore	123	109	215	29.85	29.98	−.01	75.5	+2.8	96	17	84	59	19	67	30	66	65	64	3.86	.0	13	10.2	s.	34	se.	13	9	9	12	6.1	.0	.0
Washington	112	62	85	29.86	29.98	−.02	75.4	+3.2	96	16	84	59	5	67	30	67	63	70	4.55	+.4	12	6.3	sw.	34	sw.	8	9	8	13	5.8	.0	.0
Cape Henry	18	8	54	29.97	30.00		74.9	+2.0	93	11	82	61	5	68	28	70	68	79	5.52	+1.6	13	10.1	sw.	34	nw.	8	10	9	11	5.5	.0	.0
Lynchburg	686	144	184	29.28	30.01	.00	77.0	+2.4	95	6	87	61	3	67	31	68	65	73	3.88	+.1	13	6.5	sw.	26	nw.	30	9	7	14	5.7	.0	.0
Norfolk	91	80	125	29.91	30.00	.00	77.2	+2.8	94	6	86	63	8	69	30	70	66	74	6.51	+2.3	12	8.9	sw.	33	w.	8	8	7	15	6.6	.0	.0
Richmond	144	11	52	29.85	30.00	−.01	77.0	+2.9	93	17	86	62	19	68	29	69	66	75	4.99	+1.1	10	7.5	sw.	26	nw.	13	12	8	10	4.8	.0	.0
Wytheville	2,304	49	55	27.68	30.03	+.02	72.3	+3.6	88	26	83	54	5	62	31	65	63	78	4.50	+.3	16	5.7	w.	28	w.	8	5	16	9	5.7	.0	.0
South Atlantic States							80.1	+3.6										77	4.15	−0.5										5.8		
Asheville	2,253	89	104	27.74	30.02	+.01	74.6	+5.9	92	22	86	58	24	64	28	67	64	79	4.21	+.3	13	6.1	nw.	22	s.	17	6	15	9	5.9	.0	.0
Charlotte	779	63	86	29.19	30.01	.00	80.8	+5.3	98	20	91	65	9	71	30	71	67	71	4.30	+.1	11	6.9	sw.	28	sw.	9	5	11	14	6.3	.0	.0
Greensboro[1]	886	6	56	29.09	30.01		77.8		94	21	88	62	25	68	30	70	67	76	5.24		11	7.2	sw.	40	nw.	8	4	11	15	6.5	.0	.0
Hatteras	11	5	50	30.00	30.01	.00	76.8	+1.2	88	20	82	65	6	71	19	72	71	83	4.95	+.4	11	11.7	sw.	35	w.	8	11	11	8	4.9	.0	.0
Raleigh	376	103	146	29.64	30.02	+.01	79.2	+3.5	97	22	88	67	25	70	26	72	69	78	3.84	−.6	10	7.5	sw.	33	nw.	30	7	14	9	5.7	.0	.0
Wilmington	72	73	107	29.94	30.01	.00	79.8	+3.0	96	20	87	67	6	73	23	74	72	82	4.78	−.3	16	9.0	sw.	25	s.	12	9	14	7	5.4	.0	.0
Charleston	48	11	92	29.98	30.03	+.02	81.8	+2.9	97	23	88	70	13	76	20	76	74	79	6.63	+2.0	14	9.6	s.	25	se.	15	8	11	11	5.8	.0	.0
Columbia, S. C.	347	70	91	29.64	30.01	.00	81.8	+3.7	101	22	92	68	13	72	26	71	68	70	2.53	−1.6	9	7.8	s.	22	sw.	17	9	15	6	4.9	.0	.0
Greenville, S. C.	1,040	70	78	28.93	30.00		79.7	+5.6	98	22	89	66	11	70	27	70	66	69	1.97	−2.6	9	6.6	sw.	26	sw.	11	3	16	11	6.3	.0	.0
Augusta	182	62	77	29.80	30.00	−.01	82.2	+3.5	100	22	92	69	26	72	26	73	69	73	1.60	−3.1	11	5.8	s.	20	nw.	12	9	7	14	5.5	.0	.0
Savannah	65	73	152	29.94	30.01	.00	82.2	+3.2	98	23	91	69	10	74	23	74	72	82	6.00	+.7	15	9.2	sw.	35	sw.	10	5	14	11	6.3	.0	.0
Jacksonville	43	86	110	29.98	30.03	+.02	81.8	+1.9	97	22	90	70	14	74	24	74	72	80	4.82	−.5	16	6.7	s.	24	nw.	30	3	18	9	6.3	.0	.0
Florida Peninsula							81.3	+0.6										78	4.55	−1.6										5.6		
Key West	21	10	64	29.98	30.00	+.01	82.3	+.4	90	23	87	73	12	77	15	75	73	76	1.97	−2.3	9	9.1	se.	24	se.	12	7	11	12	6.1	.0	.0
Miami	25	124	168	30.01	30.04	+.04	80.8	+.8	90	24	86	71	25	76	18	74	72	75	2.20	−4.7	11	8.2	se.	28	se.	14	11	10	9	5.4	.0	.0
Tampa	35	88	197	29.99	30.03	+.02	80.8	+.6	93	11	89	70	8	73	21	74	72	84	9.48	+2.2	20	9.4	s.	41	s.	8	9	13	8	5.4	.0	.0
East Gulf States							79.9	+1.3										79	7.02	+2.4										6.8		
Atlanta[1]	976	5	72	29.00	30.00	−.01	78.8	+2.8	95	21	89	65	24	69	26	71	69	78	7.52	+3.8	15	7.4	nw.	32	s.	12	5	7	18	7.1	.0	.0
Macon	370	79	87	29.62	30.01	.00	80.6	+1.7	98	20	90	66	3	71	26	72	69	73	2.62	−1.4	12	6.2	s.	20	sw.	17	1	13	16	7.2	.0	.0
Thomasville	273	49	58	29.74	30.03	+.03	80.1	+.6	96	20	90	66	14	70	24	73	72		8.35	+2.9	19		sw.				2	20	8	6.4	.0	.0
Apalachicola	35	11	51	29.97	30.01		80.2	+.4	93	22	87	69	13	74	20	75	72	80	10.88	+5.3	12	8.2	s.	38	e.	14	5	12	13	6.5	.0	.0
Pensacola	56	149	185	29.94	30.00	+.01	79.0	−.3	90	22	84	68	1	74	14	74	72	82	8.14	+3.5	14	12.0	s.	54	se.	16	5	17	8	6.1	.0	.0
Anniston	741	9					78.2	+3.2	95	21	88	62	24	68	28				6.62	+2.5	14		w.				7	15	8		.0	.0
Birmingham	700	11	48	29.26	29.99	.00	78.6	+.7	94	21	87	65	13	70	22	71	69	80	4.97	+.5	12	6.0	s.	24	se.	8	4	11	15	6.7	.0	.0
Mobile	57	86	161	29.93	29.99	.00	80.6	+.3	94	25	88	69	7	73	23	74	72	82	9.12	+3.7	13	9.0	s.	32	s.	16	4	19	7	6.3	.0	.0
Montgomery	218	92	105	29.76	30.01	+.01	80.7	+1.1	97	21	89	68	25	72	26	73	70	79	5.35	+1.6	16	6.4	s.	21	e.	16	4	8	18	7.3	.0	.0
Meridian	375	67	92	29.59	29.98	.00	80.0	+1.9	94	23	89	68	7	71	23	73	71	82	8.77	+4.2	19	5.5	s.	29	sw.	17	0	14	16	7.5	.0	.0
Vicksburg	247	82	102	29.71	29.96	−.01	80.4	+1.4	94	27	89	68	2	72	22	73	71	78	5.48	+1.5	13	7.2	s.	24	sw.	17	3	13	14	7.0	.0	.0
New Orleans	53	76	84	29.93	29.98	.00	81.9	+1.3	95	24	89	70	25	74	25	75	72	78	6.38	+.5	14	6.0	se.	21	sw.	16	1	17	12	6.6	.0	.0
West Gulf States							80.8	+1.1										74	3.66	+0.1										5.3		
Shreveport	249	92	227	29.68	29.94	−.02	82.4	+1.7	98	24	92	68	3	73	26	73	70	73	2.58	−.9	10	10.0	s.	30	nw.	29	4	19	7	5.9	.0	.0
Bentonville	1,303	12	51	28.57	29.91	−.03	74.8	+.7	91	16	84	51	4	65	30				8.47	+4.2	13	6.3	s.	18	sw.	8	6	18	6		.0	.0
Fort Smith	463	57	82	29.46	29.93	−.01	79.1	+1.6	97	16	88	60	11	70	26	71	67	69	4.88	+1.2	10	6.9	e.	26	nw.	12	8	16	6	5.3	.0	.0
Little Rock	357	94	102	29.57	29.94	−.02	78.8	+1.4	92	27	87	65	3	71	21	71	69	76	3.14	−.6	14	7.1	s.	24	w.	27	3	15	12	6.4	.0	.0
Austin	605	68	90	29.27	29.89		82.8	+1.6	99	15	92	67	19	73	26	72	68	69	1.00	−1.4	7	8.5	s.	24	ne.	19	11	11	8	5.0	.0	.0
Brownsville	57	88	96	29.82	29.88		80.9	−1.5	91	30	87	66	1	74	21	75	73	83	6.29	+3.4	5	11.3	se.	33	ne.	1	13	13	4	4.2	.0	.0
Corpus Christi	20	11	78	29.88	29.90	−.01	81.9	+.9	91	14	88	68	1	76	16	76	74	82	5.19	+2.6	7	12.3	s.	26	s.	18	11	10	9	5.1	.0	.0
Dallas	512	220	227	29.36	29.90		80.6		98	15	89	67	19	72	24	71	68	71	2.84	−1.1	10	12.1	se.	40	ne.	23	7	13	10	5.6	.0	.0
Fort Worth	679	92	110	29.20	29.90	−.02	81.6	+1.7	98	15	91	67	19	72	23				4.04	+.7	7	11.0	s.	31	s.	12	14	11	5	3.8	.0	.0
Galveston	54	106	114	29.88	29.94	−.01	81.7	+1.0	90	14	86	64	2	78	16	75	73	77	2.58	−1.8	6	11.6	s.	32	se.	1	13	11	6	4.8	.0	.0
Houston	138	157	190	29.79	29.94		81.8	+.4	95	14	90	66	2	74	21				3.17	−1.4	8	10.1	se.	29	se.	2	5	16	9	5.5	.0	.0
Palestine	510	64	72		29.93	−.01	80.1	+1.1	94	29	88	67	2	72				76	3.14	−.5	9	7.4	s.	22	w.	19	10	8	12		.0	.0
Port Arthur	34	59	134	29.91	29.95		82.9		96	15	89	65	2	77	20	75	72	76	3.85	−1.0	5	12.1	s.	40	s.	2	4	15	11	6.1	.0	.0
San Antonio	693	111	301	29.17	29.87	−.03	83.1	+2.1	98	15	93	68	1	74	26	72	67	67	.10	−2.4	5	12.5	se.	35	e.	6	4	22	4	5.9	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau Stations, June 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							75.2	+2.4										74	5.61	+1.7										6.2		
Chattanooga	762	71	214	29.20	29.99	−.01	78.4	+3.0	95	21	88	62	12	69	28	70	67	72	4.40	+0.2	17	6.8	w.	36	nw.	22	4	14	12	6.6	0.0	0.0
Knoxville	995	66	84	28.97	30.00	.00	78.2	+4.2	97	7	88	63	12	68	28	70	66	71	4.83	+.7	16	5.1	w.	24	nw.	30	7	14	9	5.8	.0	.0
Memphis	399	78	86	29.54	29.96	−.01	79.2	+1.6	93	16	86	63	12	72	21	72	68	73	4.05	+.5	13	6.9	sw.	27	nw.	22	3	14	13	6.6	.0	.0
Nashville	546	168	188	29.43	30.00	+.01	76.7	+1.1	91	21	85	61	12	68	26	70	67	76	4.85	+.8	12	7.5	sw.	42	nw.	22	3	17	10	6.4	.0	.0
Lexington	989	6	---	28.97	30.01	+.01	74.8	+2.6	93	16	86	54	5	64	34	---	---	---	7.66	+3.6	20	---	sw.	---	---	---	11	8	11	---	.0	.0
Louisville	525	106	120	29.41	29.97	−.01	75.8	+1.1	91	26	84	56	13	68	24	69	66	75	7.00	+3.2	15	8.4	sw.	36	nw.	10	10	13	7	5.4	.0	.0
Evansville	431	76	116	29.50	29.96	−.01	76.4	+1.3	92	26	85	58	14	68	28	69	65	72	3.31	−.7	13	8.3	sw.	36	sw.	10	2	15	13	6.6	.0	.0
Indianapolis	823	98	129	29.09	29.96	−.01	74.8	+3.2	91	27	83	52	13	66	26	66	62	69	5.67	+2.0	14	7.3	sw.	36	nw.	10	6	12	12	6.1	.0	.0
Terre Haute	575	63	149	29.33	29.94	------	75.9	------	95	27	85	51	14	67	27	67	64	70	6.16	+2.2	12	8.2	sw.	38	sw.	10	6	16	8	5.5	.0	.0
Cincinnati	627	11	51	29.31	29.98	−.01	74.0	+2.8	92	16	83	53	13	65	30	68	65	80	6.29	+2.6	15	6.4	sw.	30	nw.	30	7	12	11	6.1	.0	.0
Columbus	822	90	110	29.11	29.97	−.02	74.4	+3.5	93	16	84	52	14	65	28	66	63	71	6.06	+2.8	15	8.7	s.	37	sw.	22	7	9	14	6.4	.0	.0
Dayton	900	186	213	29.01	29.96	------	73.4	+2.0	89	16	82	51	13	65	28	66	63	73	6.26	+2.5	15	9.2	sw.	48	w.	22	6	13	11	5.9	.0	.0
Elkins	1,947	65	83	28.02	30.02	+.02	70.0	+3.1	90	16	81	48	5	60	33	64	62	81	8.35	+3.3	19	4.9	w.	21	sw.	3	5	7	18	7.3	.0	.0
Parkersburg	637	77	84	29.31	29.98	−.02	74.6	+3.2	93	17	85	51	15	65	37	67	64	75	4.26	+.3	15	5.6	se.	24	nw.	30	9	10	11	5.5	.0	.0
Pittsburgh [1]	1,273	39	54	28.65	29.98	−.01	71.4	+.7	91	27	81	51	15	62	36	64	61	74	4.99	+1.2	15	9.1	sw.	34	nw.	8	7	14	9	6.1	.0	.0
Lower Lake Region							68.7	+2.0										69	3.08	−0.3									5.7		
Buffalo	768	243	280	29.14	29.96	−.01	65.7	+1.3	86	27	73	49	13	59	30	60	56	73	1.75	−1.1	10	13.7	sw.	47	w.	12	8	13	9	5.7	.0	.0
Canton	448	10	61	29.47	29.94	------	64.1	−1.0	87	28	75	40	18	53	35	58	53	68	2.39	−.9	12	8.0	w.	32	w.	12	8	11	11	5.8	.0	.0
Ithaca	836	77	100	29.08	29.97	------	67.0	------	92	28	78	41	7	56	43	60	55	68	2.41	−1.2	14	8.4	nw.	23	s.	19	7	11	12	6.1	.0	.0
Oswego	335	71	85	29.59	29.96	−.01	63.5	−1.3	89	28	72	47	14	55	34	57	53	69	2.17	−1.1	13	8.1	w.	19	n.	6	8	9	13	5.9	.0	.0
Rochester	523	86	102	29.41	29.97	.00	67.6	+1.5	87	28	76	49	7	59	33	59	53	61	3.28	+.3	10	8.6	sw.	31	sw.	12	10	12	8	5.5	.0	.0
Syracuse	596	65	79	29.34	29.97	.00	68.4	+2.8	93	28	78	47	7	59	35	---	---	---	2.21	−1.7	11	6.8	s.	20	s.	3	7	14	9	5.6	.0	.0
Erie	714	57	81	29.20	29.96	−.02	68.8	+2.6	89	7	76	51	13	61	28	63	59	71	1.73	−1.6	13	8.1	sw.	24	sw.	12	7	16	7	5.3	.0	.0
Cleveland	762	267	318	29.15	29.96	−.02	71.2	+4.1	90	7	79	53	13	63	27	63	59	69	3.25	+.1	15	12.3	s.	43	nw.	30	7	15	8	5.4	.0	.0
Sandusky	629	5	67	29.27	29.95	−.03	72.4	+3.6	91	7	82	54	14	63	29	---	---	---	4.03	+.5	15	8.2	sw.	24	sw.	10	4	14	12	6.5	.0	.0
Toledo	628	79	87	29.29	29.96	−.01	72.0	+3.3	91	6	81	49	13	63	28	64	60	70	4.91	+1.6	16	9.1	w.	32	w.	10	10	14	6	4.8	.0	.0
Fort Wayne	857	69	84	29.05	29.96	------	72.0	+2.7	91	17	82	49	13	62	29	65	61	71	4.15	+.6	15	8.4	sw.	31	sw.	10	6	13	11	6.1	.0	.0
Detroit [1]	626	5	78	29.28	29.95	−.02	70.2	+2.8	89	27	80	47	13	60	26	63	59	70	4.70	+1.1	13	9.3	e.	34	s.	10	7	12	11	6.2	.0	.0
Upper Lake Region							64.4	+1.8										76	5.29	+1.8									6.1		
Alpena	609	13	89	29.28	29.95	−.01	61.7	+1.3	88	5	70	44	13	53	31	56	52	75	4.59	+1.3	13	10.7	se.	38	nw.	7	9	11	10	5.3	.0	.0
Escanaba	612	41	49	29.26	29.91	−.03	62.2	+1.5	82	20	70	44	12	55	27	57	54	77	4.34	+1.1	13	10.4	s.	34	nw.	11	6	12	12	6.7	.0	.0
Grand Rapids	707	70	244	29.17	29.92	−.05	70.1	+2.3	92	16	80	45	12	60	37	63	59	70	7.08	+3.6	19	10.3	sw.	36	sw.	11	5	11	14	6.1	.0	.0
Lansing	878	5	90	29.01	29.94	------	68.1	+1.7	89	7	78	43	13	58	30	63	60	77	3.77	+.3	16	7.8	sw.	22	w.	11	6	13	11	5.7	.0	.0
Marquette	734	44	69	29.11	29.91	−.03	59.9	+1.0	83	19	69	40	11	51	37	57	55	84	8.86	+5.6	13	7.1	nw.	25	nw.	11	7	12	11	6.2	.0	.0
Sault Sainte Marie [1]	724	5	33	29.15	29.93	−.03	58.8	+.2	83	28	70	37	13	48	32	54	51	77	5.86	+2.9	11	7.4	se.	27	nw.	4	7	8	15	6.4	.0	.0
Chicago	673	7	131	29.21	29.92	−.04	70.8	+3.5	92	16	79	49	14	62	31	64	60	76	5.13	+1.8	15	8.6	sw.	27	s.	16	8	14	8	5.5	.0	.0
Green Bay	617	109	141	29.24	29.90	−.05	67.0	+2.1	87	6	76	44	12	59	28	61	57	72	4.56	+.9	14	10.3	s.	38	nw.	11	2	12	16	7.2	.0	.0
Milwaukee	681	97	221	29.18	29.91	−.04	68.0	+4.1	93	16	77	46	12	59	41	60	56	70	3.50	+.1	12	10.8	w.	31	sw.	16	9	9	12	6.0	.0	.0
Duluth	1,133	5	47	28.67	29.88	−.04	57.2	.0	84	27	66	39	17	48	31	52	49	82	4.34	+.4	18	11.9	ne.	34	ne.	10	8	8	14	6.3	.0	.0
North Dakota							61.6	−1.5										70	4.51	+1.0									6.2		
Moorehead, Minn	940	50	58	28.84	29.84	−.06	64.4	.0	95	5	75	43	12	54	36	58	53	70	3.92	−.1	12	8.9	s.	24	ne.	10	1	19	10	6.6	.0	.0
Bismarck	1,677	8	57	28.10	29.86	−.01	61.6	−2.1	89	5	72	39	11	51	34	55	50	69	5.42	+2.1	12	8.9	ne.	25	w.	19	5	12	13	6.6	.0	.0
Devils Lake	1,478	11	44	28.30	29.86	−.02	60.2	−1.7	87	6	71	35	9	50	32	54	49	72	4.65	+1.1	10	9.3	ne.	26	ne.	16	9	8	13	6.0	.0	.0
Lemmon, S. Dak	2,602	4	38	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Grand Forks	832	11	71	---	---	---	62.9	−.1	93	6	74	38	9	52	35	56	53	---	4.58	+1.2	14	8.2	s.	---	---	---	---	---	---	---	---	---
Williston	1,878	42	50	27.91	29.86	.00	59.0	−3.7	83	28	69	39	10	49	32	52	48	70	3.99	+.6	13	8.2	se.	32	w.	24	12	8	10	5.4	.0	.0
Upper Mississippi Valley							72.6	+2.0										72	4.17	0.0									5.8		
Minneapolis-St. Paul, Minn [1]	838	32	61	28.96	29.85	−.07	68.6	+1.1	92	1	79	45	12	59	30	62	58	73	4.95	+.7	14	11.1	s.	59	nw.	7	5	12	13	6.3	.0	.0
Springfield, Minn	1,025	4	42	---	---	---	70.8	---	92	24	81	51	11	60	35	62	58	---	4.53	---	10	6.9	e.	---	---	---	---	---	---	---	.0	.0
La Crosse	714	11	48	29.13	29.88	−.05	70.3	+2.0	92	16	80	48	12	61	32	63	60	74	1.89	−2.2	11	5.1	s.	18	w.	18	5	14	11	5.7	.0	.0
Madison	974	70	78	28.88	29.90	−.04	69.8	+2.6	91	16	78	49	13	61	35	63	59	71	2.33	−1.4	10	7.3	s.	25	nw.	7	6	8	16	6.7	.0	.0
Charles City	1,015	10	51	28.83	29.90	−.01	69.9	+3.4	93	16	80	48	14	60	31	63	59	73	4.84	+.2	13	6.5	se.	24	sw.	18	12	13	5	4.6	.0	.0
Davenport	606	66	161	29.26	29.91	−.03	73.2	+2.7	94	17	82	52	14	64	29	65	61	70	3.76	−.4	11	9.5	sw.	41	nw.	7	9	9	12	5.6	.0	.0
Des Moines	861	5	99	28.99	29.89	−.03	72.8	+2.2	94	7	82	53	14	63	31	66	62	72	7.45	+2.7	12	9.5	se.	37	nw.	7	8	14	8	5.6	.0	.0
Dubuque	699	60	79	29.16	29.89	−.04	71.8	+2.4	94	7	81	47	14	62	29	64	60	71	5.17	+.9	9	6.0	s.	19	nw.	7	8	9	13	6.0	.0	.0
Keokuk	614	64	78	29.26	29.90	−.04	74.0	+1.5	93	18	83	54	14	65	27	67	63	71	4.42	+.3	13	7.1	s.	24	w.	10	10	7	13	5.9	.0	.0
Cairo	358	87	93	29.58	29.95	−.02	76.4	+.1	90	8	84	60	14	69	23	70	67	77	2.56	−1.3	13	7.0	s.	32	sw.	9	3	11	16	7.1	.0	.0
Peoria	609	11	45	29.28	29.94	−.01	73.0	+2.1	93	16	83	48	14	63	31	66	63	75	5.53	+1.8	17	5.2	s.	16	w.	22	14	13	3	4.4	.0	.0
Springfield, Ill	636	5	191	29.26	29.93	−.02	75.3	+3.1	94	18	84	54	14	66	30	67	63	71	3.90	−.2	10	10.3	s.	35	w.	10	6	13	11	6.3	.0	.0
St. Louis	568	179	303	29.34	29.93	−.02	76.2	+1.2	94	18	84	58	11	68	25	68	64	70	3.24	−.6	11	11.1	s.	34	sw.	10	4	19	7	5.6	.0	.0
Missouri Valley							73.2	+2.0										67	5.25	+0.9									5.4		
Columbia, Mo	784	6	66	29.08	29.89	−.06	75.0	+2.2	92	16	84	56	14	66	25	---	---	---	3.12	−1.6	10	7.5	s.	29	w.	10	5	14	11	6.2	.0	.0
Kansas City [1]	750	32	45	29.07	29.87	−.05	76.0	+2.4	96	16	86	57	4	67	29	67	64	69	10.99	+6.0	12	8.4	s.	50	w.	10	6	11	13	6.0	.0	.0
St. Joseph	967	11	49	---	29.87	------	75.1	+1.4	97	15	85	57	3	65	27	---	---	70	7.52	+2.6	16	8.1	s.	30	nw.	10	8	18	4	---	.0	.0
Springfield, Mo	1,324	5	78	28.56	29.94	−.01	74.5	+2.0	93	16	84	53	4	65	27	68	64	75	3.68	−1.0	15	8.0	s.	24	s.	9	7	17	6	5.4	.0	.0
Topeka	987	65	87	28.83	29.86	------	76.2	+2.8	98	16	87	56	11	65	31	67	63	67	5.63	+1.0	18	9.4	s.	32	sw.	14	8	14	8	5.4	.0	.0
Lincoln	1,189	11	81	28.61	29.84	−.06	74.6	+3.2	99	16	86	51	3	63	33	65	60	64	4.16	−.2	14	9.7	s.	37	nw.	10	8	15	7	5.0	.0	.0
Omaha [1]	982	31	44	28.83	29.86	−.05	74.0	+2.4	100	16	85	53	12	63	29	65	60	68	5.42	+.9	14	10.9	se.	36	sw.	22	8	11	11	5.4	.0	.0
Valentine	2,598	47	54	27.19	29.85	−.01	66.0	−.9	93	5	77	41	12	55	38	57	51	63	4.09	+1.2	13	10.2	s.	36	w.	15	12	12	6	4.6	T	.0
Sioux City	1,138	64	106	28.66	29.83	−.07	72.4	+2.9	98	16	83	51	11	62	32	63	57	64	4.31	+.3	10	9.8	s.	32	se.	17	12	8	10	5.3	.0	.0
Huron [1]	1,289	27	41	28.48	29.83	−.05	68.3	+2.1	95	5	80	45	12	57	37	60	55	67	3.60	−.2	13	13.3	nw.	52	nw.	27	11	10	9	5.2	.0	0
Northern Slope							59.3	−1.8										59	2.49	+0.2									6.1		
Havre	2,507	11	67	27.29	29.90	+.05	58.4	−3.6	90	30	69	43	15	48	35	50	45	67	3.60	+.7	18	8.7	w.	33	w.	30	4	13	13	6.6	.0	.0
Helena	4,124	85	111	25.76	29.91	+.03	55.6	−3.6	85	29	66	35	2	45	35	46	38	56	2.63	+.3	14	8.1	sw.	27	sw.	16	2	10	18	7.9	T	.0
Missoula	3,263	80	91	---	---	---	57.8	−2.2	94	29	69	37	2	46	41	---	---	---	2.14	+.2	16	6.9	w.	33	e.	14	5	8	17	7.1	.0	.0
Kalispell	2,973	48	56	26.90	29.93	+.04	54.8	−2.9	90	29	65	35	2	44	38	48	42	69	3.80	+1.7	18	5.4	w.	25	ne.	1	3	12	15	7.2	.0	.0
Miles City	2,371	48	55	27.41	29.86	+.01	61.6	−4.4	90	4	72	42	3	52	35	53	48	65	4.11	+1.4	15	6.9	w.	36	nw.	23	5	12	13	6.8	.0	.0
Rapid City	3,259	50	58	26.54	29.84	−.01	64.0	−.2	96	4	76	40	3	52	40	53	44	55	2.16	−1.2	11	8.7	n.	30	w.	18	9	14	7	4.9	.0	.0
Cheyenne [1]	6,144	5	39	23.94	29.82	−.02	61.2	+.8	92	27	76	36	19	46	40	48	38	49	.83	−.8	13	11.5	nw.	48	nw.	9	7	17	6	5.1	.0	.0
Lander	5,352	60	68	24.60	29.82	−.03	59.4	−1.1	84	28	73	36	7	46	39	48	38	51	.80	−.4	4	6.3	sw.	32	sw.	13	7	15	8	5.4	.0	.0
Sheridan	3,790	10	47	26.04	29.89	------	60.0	------	93	4	73	38	2	47	43	51	45	67	2.28	+.2	15	5.7	nw.	30	nw.	23	7	17	6	5.4	.0	.0
Yellowstone Park	6,235	12	46	23.87	29.98	+.12	50.7	−2.7	80	30	63	32	10	38	37	42	35	63	1.53	−.1	13	8.4	sw.	31	sw.	23	3	15	12	6.6	T	.0
North Platte	2,821	11	51	26.98	29.84	−.02	69.6	+2.1	101	17	82	43	11	57	37	58	52	62	3.51	+.3	14	8.6	s.	29	w.	25	17	9	4	3.7	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau Stations, June 1939*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean mat.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Middle Slope							74.4	+2.5										55	3.86	+0.8										4.2		
Denver	5,292	106	113	24.69	29.82	−0.02	68.8	+2.5	94	16	83	45	19	55	39	51	38	40	0.57	−0.8	5	8.5	s.	35	nw.	9	9	18	3	4.3	0.0	0.0
Pueblo	4,690	79	86	25.24	29.81	−.02	71.6	+2.6	99	14	87	48	22	56	42	53	40	42	.05	−1.3	3	8.1	e.	34	sw.	15	20	10	0	3.0	.0	.0
Chadron, Nebr.	3,439	4	58																												
Concordia	1,392	50	58	28.40	29.84	−.06	75.0	+2.0	100	16	86	50	11	64	31	65	59	62	3.33	−1.1	9	8.4	s.	26	s.	14	11	13	6	4.2	.0	.0
Dodge City	2,509	10	86	27.29	29.82	−.05	76.0	+3.5	104	17	89	53	3	63	34	62	54	56	2.48	−.8	11	13.3	s.	37	s.	16	16	12	2	3.3	.0	.0
Wichita	1,358	85	93	28.46	29.85	−.06	76.4	+2.0	98	7	87	54	11	66	30	66	60	63	8.90	+4.5	13	10.8	se.	38	nw.	8	13	12	5	4.5	.0	.0
Oklahoma City	1,214	10	47	28.64	29.85	−.06	78.4	+2.4	98	16	88	55	4	68	29	69	65	69	7.83	+4.2	12	10.2	s.	26	nw.	11	9	10	11	5.6	.0	.0
Southern Slope							80.6	+2.6										59	3.46	+1.0										3.4		
Abilene	1,738	10	56	28.08	29.83	−.05	82.6	+3.4	103	9	94	61	4	71	31	68	61	57	4.30	+1.3	7	11.4	s.	37	sw.	18	15	12	3	4.0	.0	.0
Amarillo	3,676	10	49	26.20	29.83	−.02	76.6	+3.8	107	15	90	56	4	64	39	60	47	47	7.59	+4.8	11	10.1	se.	31	se.	29	19	10	1	2.9	.0	.0
Del Rio	960	63	71	28.84	29.80	−.05	84.0	+.6	99	16	94	64	2	74	30	71	65	59	1.27	−1.3	4	11.8	se.	40	nw.	2	8	16	6	5.0	.0	.0
Roswell	3,566	75	85	26.28	29.78	−.02	79.1	+2.8	107	14	94	56	4	64	41	59	44	38	.66	−1.0	4	9.2	s.	31	nw.	30	25	5	0	1.7	.0	.0
Southern Plateau							75.5	+1.6										27	T	−0.4										1.5		
El Paso	3,778	82	101	26.10	29.75	.00	83.6	+4.0	106	13	97	61	5	70	35	58	36	22	T	−.6	0	9.2	w.	28	ne.	22	26	4	0	1.5	.0	.0
Albuquerque [1]	4,972	5	39	25.00	29.76	.....	74.3	+1.7	101	14	92	46	19	57	45	51	29	25	T	−.5	0	9.8	w.	40	nw.	30	18	12	0	2.7	.0	.0
Santa Fe	7,013	38	53	23.28	29.82	+.01	67.5	+2.7	89	14	81	45	18	54	34	47	28	28	.01	−1.1	1	7.0	sw.	26	sw.	15	16	13	1	2.7	.0	.0
Flagstaff	6,907	10	59	23.37	29.78	.00	60.0	+.7	90	12	78	25	18	42	45	43	.....	32	T	.....	1	10.3	sw.	30	sw.	5	19	11	0	3.0	.0	.0
Phoenix	1,107	39	51	28.62	29.74	.00	85.9	+1.4	109	12	102	60	18	70	38	59	37	21	.00	−.1	0	6.1	w.	23	nw.	14	28	2	0	.9	.0	.0
Yuma	141	9	54	29.60	29.74	.00	85.1	+.4	113	12	103	58	6	67	41	63	46	34	.00	.0	0	5.8	w.	22	w.	14	30	0	0	.0	.0	.0
Independence	3,957	5	26	.....	.....	.....	72.3	.0	98	11	86	44	17	58	38	51	30	...	.00	−.1	0	.....	n.	...	.....	...	30	0	0	.0	.0	.0
Middle Plateau							65.9	+0.9										33	0.09	−0.3										3.3		
Reno	4,527	61	76	25.43	29.89	+.03	64.1	+1.7	92	28	79	33	17	49	40	48	33	37	.06	−.2	1	7.9	w.	31	w.	14	22	8	0	2.3	T	.0
Tonopah	6,090	12	20	.....	.....	.....	66.3	.....	90	29	79	30	17	53	33	47	29	28	.00	.....	.....	.....	nw.	.....	.....	.....	.....	.....	.....	.....	.0	.0
Winnemucca	4,344	18	56	25.56	29.88	.00	63.4	+.6	96	29	81	33	17	46	46	46	30	35	.11	−.6	2	7.3	w.	31	w.	15	15	10	5	3.8	T	.0
Modena	5,473	10	46	24.56	29.79	−.03	63.8	+.5	93	29	81	29	6	46	44	45	25	28	.09	−.2	2	12.0	sw.	44	sw.	4	19	8	3	2.7	T	.0
Salt Lake City [1]	4,227	32	46	25.66	29.83	−.02	64.8	.....	96	28	80	37	17	50	41	50	37	43	1.08	.....	6	10.1	se.	39	sw.	30	13	13	4	4.5	.0	.0
Grand Junction	4,602	60	68	25.30	29.80	−.03	72.2	+.8	98	13	86	42	19	58	37	50	29	25	.11	−.3	2	8.4	n.	40	s.	15	16	14	0	3.0	.0	.0
Northern Plateau							62.3	−1.7										47	0.50	−0.5										5.5		
Baker	3,471	36	54	26.42	29.95	.00	56.4	−2.2	96	29	71	30	5	42	46	46	36	54	.60	−.7	7	6.0	n.	22	n.	3	8	15	7	5.3	.0	.0
Boise	2,739	79	87	27.10	29.92	+.01	63.1	−2.2	98	29	77	38	6	49	39	49	37	45	.38	−.5	6	6.1	nw.	24	s.	3	11	11	8	4.9	.0	.0
Pocatello [1]	4,478	5	31	25.42	29.87	.00	61.0	.....	94	29	76	35	7	46	43	47	34	43	.42	.....	6	11.8	w.	37	w.	15	10	13	7	5.0	.0	.0
Spokane	1,929	101	110	27.91	29.94	.00	60.8	−2.0	98	29	72	40	1	50	33	49	40	54	.71	−.6	12	7.4	s.	25	w.	24	7	10	13	6.2	.0	.0
Walla Walla	991	57	65	28.88	29.94	−.02	65.8	−.7	102	28	77	47	1	55	37	52	39	43	.75	−.4	8	6.9	s.	18	w.	18	5	13	12	6.1	.0	.0
Yakima	1,076	58	67	28.80	29.94	.....	65.2	−1.2	96	28	78	40	16	53	34	52	40	44	.08	−.5	4	7.3	nw.	22	nw.	3	8	15	7	5.3	.0	.0
North Pacific Coast Region							58.9	−0.4										72	1.53	−0.1										6.8		
North Head	211	8	56	29.86	30.08	+.09	55.1	+.3	63	27	59	47	16	51	15	52	50	87	2.18	−.1	18	14.0	n.	37	s.	15	1	12	17	7.9	.0	.0
Seattle	125	90	321	29.90	30.03	+.03	59.8	+.8	79	28	67	47	1	52	26	53	48	70	1.58	+.2	16	8.6	s.	27	sw.	15	4	7	19	7.3	.0	.0
Tacoma	263	172	201	29.85	30.03	+.02	58.6	−.1	77	21	66	44	1	51	25	...	...	...	1.20	−.3	11	8.8	sw.	27	sw.	14	4	11	15	6.7	.0	.0
Tatoosh Island	86	9	55	29.97	30.07	+.05	52.4	−.6	60	9	55	46	16	50	11	50	48	88	2.13	−1.1	16	8.7	sw.	29	e.	8	2	7	21	8.3	.0	.0
Medford [1]	1,329	29	58	28.61	30.00	.....	63.8	−1.4	95	21	79	39	1	49	47	52	43	54	.40	−.3	3	.....	nw.	...	.....	...	12	7	11	4.8	.0	.0
Portland, Oreg.	154	68	106	29.89	30.05	+.01	61.3	−1.1	86	28	70	47	25	53	30	54	49	68	1.73	+.2	10	6.3	nw.	15	nw.	22	8	4	18	6.8	.0	.0
Roseburg	510	45	76	29.50	30.05	+.02	61.6	−.9	88	21	74	41	6	50	40	53	46	63	1.52	+.4	8	5.3	n.	18	n.	20	9	7	14	5.8	.0	.0
Middle Pacific Coast Region							65.0	+0.6										60	0.15	−0.4										3.7		
Eureka	60	72	88	30.01	30.08	+.03	54.0	−.3	63	21	58	44	4	50	15	51	49	84	.56	−.2	4	8.2	n.	24	nw.	23	7	10	13	6.3	.0	.0
Redding [1]	722	20	34	.....	.....	.....	75.5	+.4	102	22	88	49	17	63	30	56	38	30	.04	−.8	1	9.8	nw.	32	nw.	15	20	6	4	2.9	.0	.0
Sacramento	66	92	115	29.79	29.86	−.03	72.6	+3.2	103	22	89	46	4	56	39	57	45	46	T	−.2	0	8.0	s.	23	sw.	3	23	7	0	1.5	.0	.0
San Francisco	155	112	132	29.77	29.94	−.02	57.8	−.7	74	7	64	49	6	52	23	52	49	78	T	−.2	0	10.9	w.	30	w.	5	17	9	4	3.3	.0	.0
South Pacific Coast Region							69.4	+0.7										59	0.55	+0.5										2.7		
Fresno	327	97	105	29.50	29.84	−.01	76.5	+.7	104	22	92	49	4	61	38	57	40	34	1.66	+1.6	1	7.4	nw.	40	se.	14	23	7	0	1.5	.0	.0
Los Angeles	338	159	191	29.55	29.91	+.01	66.9	+.5	84	30	76	55	6	58	26	59	54	68	T	−.1	0	5.7	sw.	17	sw.	14	21	9	0	2.6	.0	.0
San Diego	87	62	70	29.82	29.91	−.01	64.8	+.9	76	9	70	54	7	60	18	59	56	76	.00	.0	0	7.2	w.	16	w.	11	15	12	3	4.1	.0	.0
West Indies																																
San Juan, P. R.	82	9	54	29.95	30.04	.....	78.4	−1.3	87	25	82	70	18	75	13	.....	.....	...	3.17	−2.1	12	13.2	e.	36	e.	20	7	16	7	5.7	.0	.0
Panama Canal																																
Balboa Heights	118	6	92	.....	[3]29.83	.00	80.7	+.6	91	3	87	71	21	74	19	.....	.....	[3]85	12.65	+4.3	19	5.2	nw.	22	nw.	3	0	18	12	7.2	.0	.0
Cristobal	36	6	97	.....	[3]29.85	+.02	81.4	+1.0	91	11	86	73	20	77	14	76	75	[3]82	12.60	−1.3	25	7.4	n.	22	sw.	20	0	5	25	8.7	.0	.0
Alaska																																
Fairbanks	454	11	87	[3]29.40	[3]29.91	.....	59.2	+1.1	80	23	71	40	3	47	32	51	46	68	2.18	+.8	14	6.4	s.	27	ne.	13	2	17	11	6.5	.0	.0
Juneau	80	96	116	[3]29.91	[3]30.00	.....	54.7	+.4	77	15	62	39	2	47	28	49	43	72	4.65	+1.1	16	6.1	w.	19	se.	30	8	2	20	7.4	.0	.0
Nome	22	5	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hawaiian Islands																																
Honolulu	38	86	100	30.00	30.04	.....	75.4	−1.2	82	28	80	69	23	71	11	68	65	72	1.33	+.4	23	9.5	e.	23	ne.	20	3	19	8	6.3	.0	.0

[1] Observations taken at airport.

[2] Observations taken hourly.

[3] Pressure not reduced to a mean of 24 hours.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, June 1939*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99				43.0	−4.6	49.2	36.9	67	27	3.33	−1.03	
Sydney, Cape Breton Island	48	29.78	29.91	−0.04	54.2	−.8	64.5	43.8	83	35	2.71	−.14	
Halifax, Nova Scotia	88	29.70	29.96	.00	57.6	−.2	66.1	49.0	84	40	2.76	−1.22	
Yarmouth, Nova Scotia	65	29.86	29.97	+.01	54.8	−.4	63.3	46.4	74	39	3.22	+.28	
Charlottetown, Prince Edward Island	38	29.86	29.94	+.01	56.6	−.8	65.4	47.9	80	34	1.18	−1.70	
Chatham, New Brunswick	28	29.81	29.92	+.01	57.7	−2.0	69.2	46.2	86	36	3.14	−.38	
Father Point, Quebec	20	29.92	29.93	+.05	51.8	−.9	59.6	43.9	69	36	3.55	+.34	
Quebec, Quebec	296												
Doucet, Quebec	1,236	28.57	29.90	−.01	57.3	+2.2	70.1	44.5	82	25	4.14	+.19	
Montreal, Quebec	187												
Ottawa, Ontario	236	29.57	29.94	+.02	64.0	−.5	74.7	53.3	86	43	2.70	−.49	
Kingston, Ontario	285	29.66	29.97	+.03	61.2	−1.4	73.2	49.1	87	39	2.60	−.90	
Toronto, Ontario	379	29.55	29.96	−.01	65.5	+1.3	74.1	56.9	89	47	1.91	−.90	
Cochrane, Ontario	930												
White River, Ontario	1,244	28.59	29.92	.00	57.9	+.7	69.5	46.3	86	31	5.73	+3.25	
London, Ontario	808	29.12	29.98		65.3	+.5	75.8	54.8	86	40	4.22	+1.17	
Southampton, Ontario	656	29.24	29.94	−.01	61.7	+1.4	72.2	51.2	84	39	4.28	+1.73	
Parry Sound, Ontario	688	29.28	29.96	+.02	62.2	+.3	71.6	52.9	84	44	3.25	+.68	
Port Arthur, Ontario	644	29.20	29.91	−.02	56.5	−.5	65.5	47.5	84	36	3.28	+.43	
Winnipeg, Manitoba	760	29.01	29.87	−.04	59.0	−3.4	69.7	48.4	86	37	2.49	−.59	
Minnedosa, Manitoba	1,690	28.10	29.89	+.02	55.5	−4.4	66.1	44.4	79	28	2.32	−.66	
Le Pas, Manitoba	860	28.96	29.93	+.02	53.2	−6.0	64.3	42.1	78	33	5.18	+2.96	
Qu'Appelle, Saskatchewan	2,115	27.64	29.90	+.03	55.0	−4.7	66.3	43.8	78	30	5.46	+1.97	
Moose Jaw, Saskatchewan	1,759	27.93	29.91	+.08	55.8	−4.5	65.8	45.8	81	35	5.38	+2.34	
Swift Current, Saskatchewan	2,392				52.9	−7.3	61.3	44.5	76	35	5.40	+2.44	
Medicine Hat, Alberta	2,365	27.43	29.91	+.05	56.0	−7.1	66.5	45.6	86	35	4.26	+1.80	
Calgary, Alberta	3,540	26.32	29.99	+.11	49.8	−6.1	58.5	41.0	81	32	7.98	+4.79	
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	28.40	29.94	+.06	54.8	−3.9	64.0	45.5	74	34	4.32	+1.55	
Battleford, Saskatchewan	1,592	28.16	29.89	+.02	54.1	−4.3	64.8	43.4	77	32	4.19	+1.31	
Edmonton, Alberta	2,150	27.61	29.96		53.0	−4.3	63.4	42.7	81	30	1.44	−1.65	
Kamloops, British Columbia	1,262	28.60	29.94	+.02	61.0	−3.5	72.0	50.0	91	39	3.12	+1.80	
Victoria, British Columbia	230	29.79	30.04	+.02	55.4	−1.6	61.8	49.1	70	44	1.23	+.33	
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20	30.03	30.06	+.02	53.4	+.4	58.2	48.7	62	41	3.71	−.01	
Prince Rupert, British Columbia	170	29.85	30.04	+.02	52.1	−1.1	58.9	45.3	64	38	3.91	−.07	
St. Georges, Bermuda	158		30.07	−.05	76.7	+2.3	82.0	71.4	86	67	1.78	−2.81	

TABLE 4.—*Severe local storms, June 1939*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as has been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Houma, La., vicinity of	1	9 p. m.		0	$300	Tornado	Syrup mill on Bayou Grand Caillon, 2 miles southeast of Houma, demolished. Path narrow and short.
Winnebago County, Iowa	2	2:30 p. m.		0	2,030	do	Several farm buildings destroyed; trees uprooted; path 6 miles long.
Verden, Okla., vicinity of	2	6 p. m.	[1] 1		5,000	Hail	Loss in cotton, corn, and oats; path 2 miles long.
Chattanooga, Tenn	2			2		Rain	Trapped in a drainage ditch by a sudden downpour of rain, 2 children were drowned.
Tacoma, Wash	3	P. m.				Thunderstorm	Electrical damage reported; 2 golfers stunned; several residences struck by lightning.
Tracy, Minn	4					Dust	Many cornfields damaged, some fields being completely stripped.
Hanson, McCook, Turner, Minnehaha Counties, S. Dak.	7	1–2 a. m.	[1] ½–20		500,000	Heavy hail	Property damage, $425,000; loss to crops, $75,000.
Rock and western Nobles Counties, Minn.	7	2:15 a. m.	[1] 20		75,000	Hail	Loss to crops, $50,000; property damage, $25,000.
Minnesota, extreme southern counties.	7	2:15–6 a. m.			725,000	Thundersqualls	3 persons injured; property damaged; trees uprooted; wires down.
Polk, Barron, Rusk, St. Coix, Dunn, Pierce, Pepin, and Eau Claire Counties, Wis.	7	5:30–6:30 a. m.	[1] 90		171,000	Straight-line wind.	Greatest destruction in Barron County where a man was seriously injured and from 80 to 100 barns were blown down. In other localities in this area, numerous silos, small buildings, and some barns were wrecked. Path 100 miles long.
Ada, Minn., and vicinity	7	6:40 a. m.	[1] 10		1,000	Thundersquall	Property damaged.
Marquette, Mich	7	A. m.			25,000	Thunderstorm	Lumber mill damaged by fire.
Cass County, Iowa	7	2 p. m.			11,000	Wind and hail	Damage mostly to buildings.
Adams County, Iowa	7	3–3:30 p. m.			67,400	do	15 persons injured; damage to buildings and trees; small crop loss.
Knoxville, Iowa	7	4 p. m.			3,000	Wind	Property damaged.
Marion County, Iowa	7	do	167	0	1,000	Tornado	No details.
Polk County, Iowa	7	4:30 p. m.			5,000	Electrical and wind.	Several trees blown over; transformers hit.
Indianola, Iowa	7	4:45 p. m.			10,800	Wind	Property damaged.
Keats to Manhattan, Kans	7	5:30 p. m.	[1] 2		12,000	Heavy hail	Much damage in and near Manhattan, especially to the State College experiment farm. Chief damage to wheat with small damage to greenhouses; path 20 miles long.
Clinton County, Iowa	7	8 p. m.			700	Wind	Trees blown down; electric service interrupted.
Montgomery County, Iowa	7	P. m.				Wind and hail	Buildings demolished; cars blown off the highway between Villisca and Clarinda. In Villisca, rainfall measured more than 4 inches in an hour; caused flooding in the lowlands.

[1] Miles instead of yards.

TABLE 4.—*Severe local storms, June 1939*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Grant, Rock, and Fond du Lac Counties, Wis.	7	P. m.			$18,000	Wind	Property damaged.
Vilas County, Wis., extreme eastern portion.	7			2		do	2 men drowned when their rowboat capsized in the strong wind.
Hutchinson, Kans., northern portion to Buhler, Kans.	8	5:30–6 p. m.	[1] 5		18,000	Heavy hail	Chief damage to wheat and other crops; path 15 miles long.
McPherson County, Kans.	8	6:30 p. m.	200	0	5,000	Tornado	Originated 3 miles north of Mound Ridge. Damage to farm property; 2 persons injured; path 2 miles long.
Croft to Isabel, Kans.	8	6:30–8 p. m.	[1] 15		65,000	Heavy hail	Chief damage to wheat; path 27 miles long.
Ellis County, Kans., southwestern portion.	8	8 p. m.	[1] 6		25,000	do	Loss mostly in wheat; path 10 miles long.
Howard, Kans., 10 miles northeast.	8	do	67	0	1,000	Tornado	Funnel-shaped cloud observed; path 1 mile long.
Sedgwick County, Kans.	8	do	[1] 15–20		110,000	Wind and hail	Wind damages in Wichita, alone, $50,000; small loss from hail in northern portion of the county.
Harvey County, Kans., northeastern portion.	8	P. m.			12,000	Heavy hail	Loss in wheat.
Iowa City, Iowa, 9 miles south	9	Noon		0		Tornado	Board fence torn up; fruit trees uprooted; path narrow and short.
Atlanta to Hildreth, Nebr.	9	7:30 p. m.	[1] 9		125,000	Wind and hail	Property damaged; about 25 percent crop loss from hail.
Jewell and Mitchell Counties, Kans.	9	9:30–12 p. m.	[1] 25		55,000	Heavy hail and wind.	Hail damage chiefly to wheat; wind damaged property to the extent of $10,000; path 30 miles long.
Clay County, Kans.	9	11–11:30 p. m.			100,000	do	Loss in wheat from hail.
Mont Clare, S. C.	9	P. m.		0	1,500	Tornado	Lumber mill damaged; 3 smokestacks blown down; roofs damaged. Storm moved from the west; path narrow.
Weld County, Colo., central portion.	9			1		Wind	Loss to crops; trees blown across highways; 1 person injured.
Smith Center, Kans.	9			0		Tornado	Several bridges blown down; path narrow and short.
Orangeburg, S. C., vicinity of	9				3,000	Electrical	Barn with equipment burned.
Marysville, Kans., vicinity of	9–10				1,500	High winds	Damage to barns and small farm buildings.
Benton, Jasper, White, and Lake Counties, Ind.	10	4 p. m.		1	110,000	Wind	Loss to crops, $10,000; property damage, $100,000.
Benton and Newton Counties, Ind.	10	do	200	0	55,000	Tornado	Crop loss, $5,000; property damage, $50,000; path 15 miles long.
Cass County, Ind.	10	5 p. m.			50,000	Wind	Property damaged.
Porter County, Ind.	10	do			10,000	do	Do.
Vigor County, Ind.	10	do			3,000	do	Do.
Indianapolis, Ind.	10	6:28–8:33 p. m.				Thundersquall	Power and telephone lines damaged; basements and sewers flooded by heavy rain; trees and shrubbery damaged by wind.
Camden and Flowerfield, Mich.	10	6:30–7 p. m.		0		2 tornadoes	The Camden tornado moved northeastward to Rollin, Lenawee County and the Flowerfield one moved northeastward and passed west of Vicksburg, Kalamazoo County. Funnel-shaped clouds observed in both storms.
Delaware County, Ind.	10	8 p. m.			5,000	Wind	Property damaged.
Williams, Fulton, Lucas, Defiance, Henry, and Wood Counties, Ohio.	10	P. m.		1	210,000	do	5 persons injured; small crop loss.
Kosciusko County, Ind.	10	do			10,000	do	Property damaged.
Putnam County, Ind.	10	do			5,000	do	Do.
Atlanta, Ill.	10				500	do	Do.
Beloit, Wis.	10			1	1,600	Thunderstorm	Buildings damaged; baby killed by flying glass.
Ford and Champaign Counties, Ill.	10				50,000	Wind	Property damaged; 6 persons injured.
Heyworth, Ill.	10				7,100	do	Property damaged; crop loss about 25 percent; 2 persons injured.
Iola, Ill.	10				1,500	do	Property damaged.
Jacksonville, Ill.	10				43,060	Wind, electrical	Property damaged; 2 persons injured; residence burned with $3,000 damage.
Loda, Ill.	10				15,000	Wind	Property damaged.
Milford, Ill.	10				37,000	Heavy hail	$12,000, property damage; $25,000, crop loss.
Momence, Ill.	10				75,000	Wind	Property damaged; 1 person injured.
Monticello, Ill.	10				500	do	Property damaged.
Montgomery County, Tenn.	10				6,000	do	No details.
Okawville, Ill.	10				8,000	do	Loss to crops.
Plainville, Ill.	10				1,000	Electrical	Property damaged; 1 person injured.
Salem, Ill.	10				5,000	Wind	Damage to buildings, orchards, and shade trees.
Sheldon, Ill.	10				10,000	Hail	Property damaged.
Waynesville, Ill.	10				6,000	Wind	Property damaged.
Wellington, through Stockton to Sheldon, Ill., into Indiana.	10		200–450	0	132,250	Tornado	12 persons injured; property damaged, $127,250; crop loss, $5,000; path, 25 miles long in Illinois.
Erick, Okla.	11	4 p. m.	[1] 2		18,000	Wind	Loss to crops, $12,000; damage to property, $6,000; path, 23 miles long.
Grant County, Kans.	11	4–5 p. m.	[1] 5		16,000	Heavy hail	Loss in 4,000 acres of wheat; path, 20 miles long.
Seward County, Kans.	11	5:30 p. m.	[1] 3		8,000	Tornadic wind and hail.	$3,000 crop loss; $5,000 property damage; path, 20 miles long.
Texas County, Okla.	11	6:30 p. m.			20,000	Heavy hail and and wind.	2 areas were affected, the one to the west of Hooker being 4 to 5 miles wide and 12 miles long, while the one to the east was 2 to 3 miles wide and 6 miles long. Chief loss in wheat.
Natural Bridge and Cranberry Lake, N. Y., vicinity of.	11					Thundersquall	Many trees blown down; electric service interrupted; roads blocked.
Grandfield and Devol, Okla., and vicinities.	12	7 a. m.	[1] 9		55,000	Hail and wind	Loss in cotton, wheat, and poultry; path, 12 miles long.
Burkburnett, Tex.	12	7:40 a. m.	[1] 6		100,000	Hail	90 percent of crops destroyed; $100,000 property damage.
Buffalo, N. Y., and vicinity	12	7:49 a. m.				Wind	Storm somewhat hazardous for pedestrians; church window demolished; power line snapped; damage to small boats in the harbor; much loss to grapes along the Lake Shore.
Miami, Tex.	13	6:30 a. m.	[1] 10			Hail	Wheat and all other crops totally destroyed.
Brooksville, Fla.	13	11:05 p. m.	220–440	0	600	Tornado	Several buildings moved from foundations; roofs damaged; path, 20 miles long.
Custer County, Mont.	14	1 a. m.	[1] 1		1,120	Wind and hail	Loss to crops; path, 18 miles long.
Trego, Ness, Rush, Pawnee, and Edwards Counties, Kans.	14	3–6 a. m.	[1] 25	0	185,000	Tornado and hail	West of McCracken, a tornado cloud was observed, but its path and damage were obscured by the general storm. Greater part of loss to wheat from hail; path 70 miles long.
Sigourney, Iowa	14	9:30 a. m.	7–10	0	500	Tornado	Most damage to small buildings on 2 sites.
Graham County, Kans., southern portion.	14	2 p. m.	[1] 5		20,000	Heavy hail and wind	Loss in barley and wheat; path 10 miles long.
Fresno, Calif., and vicinity	14	P. m.			32,000	Wind, rain and hail.	Property damage from wind and overflow, $27,000; loss to crops from hail, $5,000.
Grant County, Wis.	14	do			1,000	Thundersquall	Damage to buildings and electric wires.
Bassett, Iowa	14				1,000	Electrical	Church struck by lightning.
Aspen, Colo.	15	9 a. m.–3 p. m.	[1] 2		4,000	Wind	Property damaged.
Mitchell, Nebr.	15	8 p. m.	[1] 20		10,000	Hail	Loss to crops; property damaged.
Alliance, Nebr.	15	8:30 p. m.	[1] 10		75,000	do	Principal damage to buildings and automobiles; small crop loss.
Day County, S. Dak.	15	P. m.			7,100	Rain and flood	2.68 inches of rain in less than an hour. Propety damage, $6,100; crop loss, $1,000.

[1] Miles instead of yards.

TABLE 4.—*Severe local storms, June 1939*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Buffalo, N. Y.	15				$1,560	Thunderstorm	2 houses, a church, and barn with outbuildings damaged by fire.
Castlewood, S. Dak., vicinity of.	16	2 a. m.	20		800	Wind	Property damaged.
Milbank, S. Dak., to Minnesota.	16	3 a. m.	[1]2		25,000	do	Buildings destroyed; small crop loss.
Bigstone, Stevens, Pope, Renville, Stearns, Morrison, and Benton Counties, Minn.	16	3–4:45 a. m.	[1]20		85,000	Thundersqualls and hail.	2 persons injured; about 37 barns, outbuildings, silos and windmills wrecked; poles and wires down; many trees uprooted. Loss to growing crops, from wind, small; from hail, $30,000.
Potsdam, N. Y., western portion.	17				500	Thunderstorm	Barn burned.
Watertown, N. Y.	17				21,000	Hail	Damage to greenhouses and gardens, $20,000; loss to crops, $1,000.
Cullison, Kans., 3 miles northwest.	18	7:30 a. m.	[1]1		50,000	High wind	Damage to farm property; wheat lodged; path 5 miles long.
Anoka and Champlin, Minn.	18	3–4 p. m.		9	1,300,000	Tornado	Property damaged. Detailed account on page — of this REVIEW.
Calhoun County, Iowa	18	5 p. m.			700	Wind and hail	Considerable wind damage to buildings, trees and crops; some loss to small grain from hail.
Otoe and Johnson Counties, Nebr.	18	5:30–7 p. m.	[1]1-5		10,000	Hail	Property damaged.
Pratt, Kingman, and Reno Counties, Kans.	18	6–7:30 p. m.	[1]12–20		154,000	Wind and hail	Property damage, $4,000; loss to crops from hail, $75,000; from wind, $75,000.
Fall River and Menomonie, Wis.	18	P. m.			1,300	Thundersquall	Property damaged.
Duck River Valley, Tenn.	18					Heavy rain and flood.	Number of families forced to move; large quantities of farm products and livestock washed away.
Corpus Christi, Tex.	18				7,000	Thunderstorm	Many oil tanks struck by lightning causing several fires.
San Jose and Delavan, Ill.	19	1 p. m.	150–265	0	20,500	Tornado	Property damage, $20,000; loss to crops, $500; path 11 miles long.
Knox County, Ind.	19	4 p. m.			5,000	Wind	Property damaged.
Owen County, Iowa	19	5 p. m.	40	0	3,000	Tornado	Path from southwest to northeast; probably short.
Abilene, Tex., vicinity of.	19		440			Hail	Crops almost total loss amounting to several thousand dollars; path 2 to 3 miles long.
Bellflower, Ill.	19				2,000	Wind	Property damaged.
Lawrenceville, Ill.	19				2,000	Wind and rain	Property damaged; loss to crops.
Milton, Ill.	19				20,000	Wind	Property damaged.
Clay County, Ill.	20	11 a. m.	30		500	do	Do.
Phillips County, Kans.	20	Noon	100	0		Tornado	Path extended across open ground ¾ mile northeast of Phillipsburg. Path 440 yards long.
Atchison County, Kans.	20	1:20–2 p. m.	[1]4		30,000	Heavy hail and wind.	Storm extended from vicinity of Huron, Kans., through business section of Atchison and into Missouri. Principal damage in Atchison where basements and first floors were flooded. Some damage to wheat. Hail in places a foot deep. Path of storm 10 miles long. Damage in Missouri not included in this estimate.
Roy, N. Mex.	20	2 p. m.	[1]4		20,000	Hail	Loss to crops.
Solano, N. Mex.	20	do			2,000	do	Do.
Herndon, Kans., north of.	20	2–3 p. m.	[1]1		2,500	Heavy hail and wind.	Loss to wheat; path 6 miles long.
Hitchcock County, Nebr.	20	2:30–4:30 p. m.	[1]10		20,000	Rain and hail	Wheat fields damaged by hail; corn fields by washing.
Phillips County, Mont.	20	4 p. m.	[1]3		10,000	Heavy rain and hail.	Loss to crops, $10,000; basements flooded; path 4½ miles long.
Morgan County, Ind.	20	5 p. m.	900		5,000	Wind	Property damaged.
Richland County, Mont.	20	do	[1]2		5,000	Heavy rain and hail.	2 bridges washed out, 3 others damaged; path 8 miles long.
Talmo and Hollis, Kans., and vicinities.	20	do	[1]2			Heavy hail	Loss in wheat from 40 to 90 percent; path 7 miles long.
Cloud County, Kans.	20	5:25 p. m.	17	0	50	Tornado	Funnel-shaped cloud observed; path 67 yards long.
Republic County, Kans.	20	5:45 p. m.	[1]2	0	15,000	do	Storm occurred over strip extending from Cuba toward the southeast. Small damage to buildings in Cuba and to adjacent farm property; path 5 miles long.
Opdyke, Shallowater, and Monroe, Tex.	20	6:20 p. m.	[1]4	1	27,500	do	20 persons injured; property damage, $27,500; crop loss negligible.
Cordell, Okla., vicinity of.	20		[1]2		30,000	Hail	Loss in cotton, wheat and gardens; path 6 miles long.
Day County, S. Dak.	21	2:45 p. m.		0	500	Tornado	Property damaged; path narrow.
Olanta, S. C., vicinity of.	21	3:30 p. m.		0	5,000	do	Mule and a number of hogs killed when a barn collapsed; roof of tenant house blown away; mother and 2 children injured by falling timber.
Ford County, Kans., vicinity of.	21	3–4 p. m.	[1]1		8,000	Heavy hail	Loss to crops; damage to buildings; path 6 miles long.
Winnebago County, Ill., northwestern portion.	21	4 p. m.	400	0	19,000	Tornado	Property damage, $15,000; crop loss, $4,000; path 3 miles long.
Richland County, Mont.	21	4:30 p. m.	[1]3		4,000	Heavy rain and hail.	Soil washed; poultry killed; path 7½ miles long.
Hall County, Nebr.	21	5:20–6:30 p. m.	[1]2		75,000	Hail and wind	Chief damage to roofs and windows; loss to grain in small area.
Forgan, Okla., vicinity of.	21	5:30 p. m.	[1]5		17,000	Rain and hail	Hailstones fell in great quantity accumulating in some areas a depth of 5 inches and in low places to a depth of 18 inches. Calves and other small farm animals in open killed. Loss in wheat, $15,000; property damage, $2,000; path 15 miles long.
Lumber City, Ga., 7 miles west.	21	9 p. m.			5,000	Hail	Loss to crops.
Joliet, Ill.	21				10,000	Wind	Damage principally to wires and trees.
Pittwood, Ill.	21				1,500	do	Property damaged.
East Moline, Ill.	22	A. m.				Rain, hail, and wind.	Property damage estimated to be several thousand dollars.
Dayton, Ohio and vicinity.	22	2:12–2:17 p. m.			26,000	Thunderstorm	Trees uprooted; buildings damaged; poor visibility due to heavy rain. Damage in Dayton, $20,000. Loss of $6,000 in Camden and Brookville when 2 barns with contents burned and some livestock were killed.
Purcellville, Va., vicinity of.	22	3–5 p. m.	141		15,000	Wind and hail	Loss to crops, principally corn, $10,000; damage to buildings, $5,000.
Hamilton County, Nebr.	22	6 p. m.	[1]2		60,000	Hail	Loss in corn and small grains.
Las Vegas, N. Mex.	22	do	1,320		250,000	do	Crop loss, $25,000; property damage, $225,000.
State Lake, Kans., vicinity of.	22	6:30 p. m.	[1]1			Heavy hail	Roofs damaged; path 2 miles long.
Clayton, N. Mex.	22	8:45 p. m.	[1]5		700	Hail	Damage to roofs and windows.
Jonesboro, Ark.	22	P. m.			2,500	Thunderstorm	Power plant damaged by lightning.
Union City, Pa., and vicinity.	22					Thundersquall	House unroofed; trees blown down; crops washed out; considerable damage by flooding.
Mosquero, N. Mex.	23	1 a. m.	[1]4		2,000	Heavy hail	Loss to crops.
Jefferson County, Mont.	23	11:30 a. m.	[1]12		5,325	Hail and wind	Loss to crops, $5,000; property damage, $325; path 4 miles long.
Fergus and Judith Basin Counties, Mont.	23	1:30 p. m.	[1]14		52,000	Wind and hail	Wind damage, $2,000; loss to crops, $50,000; path 80 miles long.
Phillips and Valley Counties, Mont.	23	1:30 p. m.			25,000	Hail	Loss to crops.
Petroleum and Fergus Counties, Mont.	23	2 p. m.	[1]4		10,000	do	75 to 90 percent loss of crops; path 25 miles long.
Rawlins and Thomas Counties, Kans.	23	4:30 p. m.	[1]2½		30,000	Heavy hail	Loss to wheat; path 20 miles long.

[1] Miles instead of yards.

TABLE 4.—*Severe local storms, June 1939*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Fergus County, Mont.	23	5 p. m.			$3,000	Hail	Loss to 500 acres of grain; path 15 miles long.
Daniels County, Mont.	23	7 p. m.	[1] 3		50,000	Wind and hail	Small wind damage; loss to crops; path 24 miles long.
McCone County, Mont.	23	7:15 p. m.	[1] 5		50,000	Wind, hail and rain.	Hail damage to crops; 50 to 90 percent; path 25 miles long.
Defiance, Ohio	23	P. m.			25,000	Wind and heavy rain.	Most property damage in Hicksville; some loss to wheat.
Leroy to Sterling, Colo.	24	5:20 p. m.	[1] 6		20,000	Heavy hail	Small grain crops total loss; path 7 miles long.
McDonald, Kans., and vicinity.	24	8:30-9 p. m.	[1] 2		8,000	do	Loss mostly in wheat; path 10 miles long.
Brookings and Moody Counties, S. Dak.	24	P. m.				Heavy hail and rain.	Corn stripped; loss in grain; path narrow and from 1 to 2 miles long.
Custer, Loup, Valley, and Garfield Counties, Nebr.	24-25	do	[1] 40		100,000	Excessive rain and hail.	Small streams out of banks; railroad tracks washed out; farm and homes flooded; hail damage comparatively small.
Wichita, Kans., 10 miles north.	25	9:30 p. m.		2	100,000	Wind	Storm exhibited tornadic characteristics; property damaged; path narrow and short.
Knox County, Nebr.	26	5 p. m.	[1] 3		65,000	Hail	Property damaged; loss in small grains and corn.
Marshall County, Kans.	26				8,500	Heavy rain	Bridges damaged.
Wichita, Kans., vicinity of.	26				45,000	Flood	25,000 acres of farm lands flooded with loss to uncut wheat.
Beardsley, Minn., vicinity of.	27	2:30-3:15 p. m.		1		Tornado, rain, and hail.	Storm moved from northwest to southeast over a path about 40 miles long much grain lodged. Automobile blown off the road causing a fatality and an injury.
Cotton Plant, Ark., 4 miles west.	27	P. m.			1,100	Thunderstorm	Barn destroyed; horse and mule killed.
Bonilla and Wolsey, S. Dak., and vicinities.	27	7:30-8:30 p. m.			10,000	High wind and rain.	Property damaged; crop loss negligible.
Butte and Mead Counties, S. Dak.	27	P. m.			4,000	Wind and hail	Property damaged; small crop loss.
Chautauqua Lake, N. Y.	28				15,000	Thunderstorm	Clubhouse burned.
Sedgwick County, Kans.	28				60,300	Flood	Damage to bridges, $55,300; loss to crops, $5,000.
Delaware County, Ind.	28	4 p. m.			5,000	Wind	Property damage, $5,000; loss to orchards not estimated.
New Richland, Minn., vicinity of.	28	5 p. m.	2,640		2,000	Hail	Storm moved from northwest to southeast over a path 3 miles long.
Stillwater and Carbon Counties, Mont.	28	5:45 p. m.	880		3,000	Heavy hail	Loss to crops.
Wausa, Nebr.	28	6-9 p. m.	[1] 5		6,000	Hail	Loss in small grains and corn.
Nobles County, Nebr.	28	P. m.			3,000	Thundersquall and hail.	Small buildings blown over; barns damaged; loss to crops from hail.
Pondera and Chouteau Counties, Mont.	30	2:45 p. m.	[1] 5		52,000	Wind and hail	Crop loss, $50,000 from hail; damage to property from hail, $2,000; path 30 miles long.
Kaufman, Tex., vicinity of.	30	7:30 p. m.	[1] 1		2,000	Hail	Loss to crops.
El Dorado, Ark.	30	P. m.			900	Thunderstorm	Oil property struck by lightning and 18,667 gallons of oil burned.

[1] Miles instead of yards.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, and Wind Roses for Selected Stations, June 1939

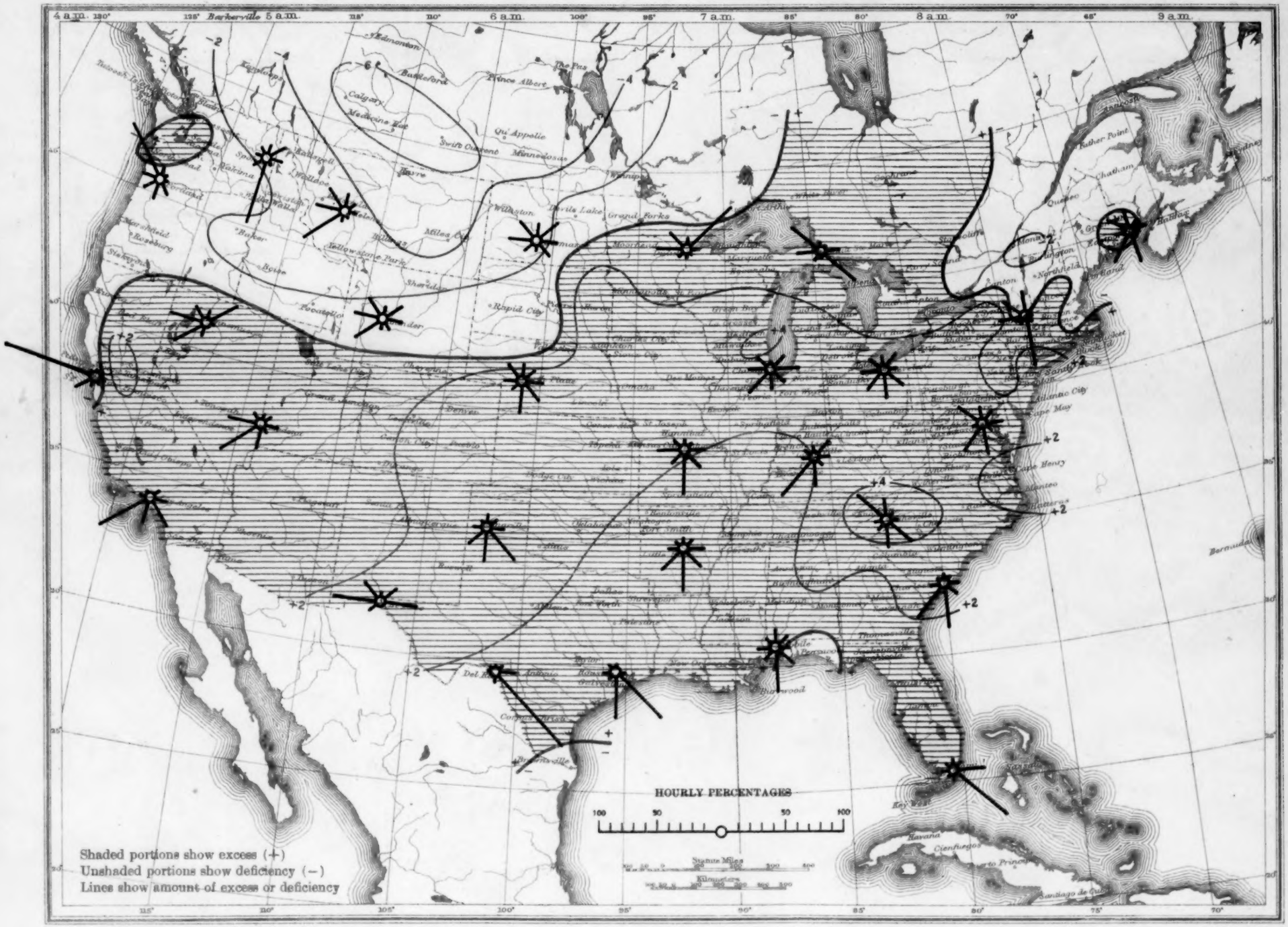
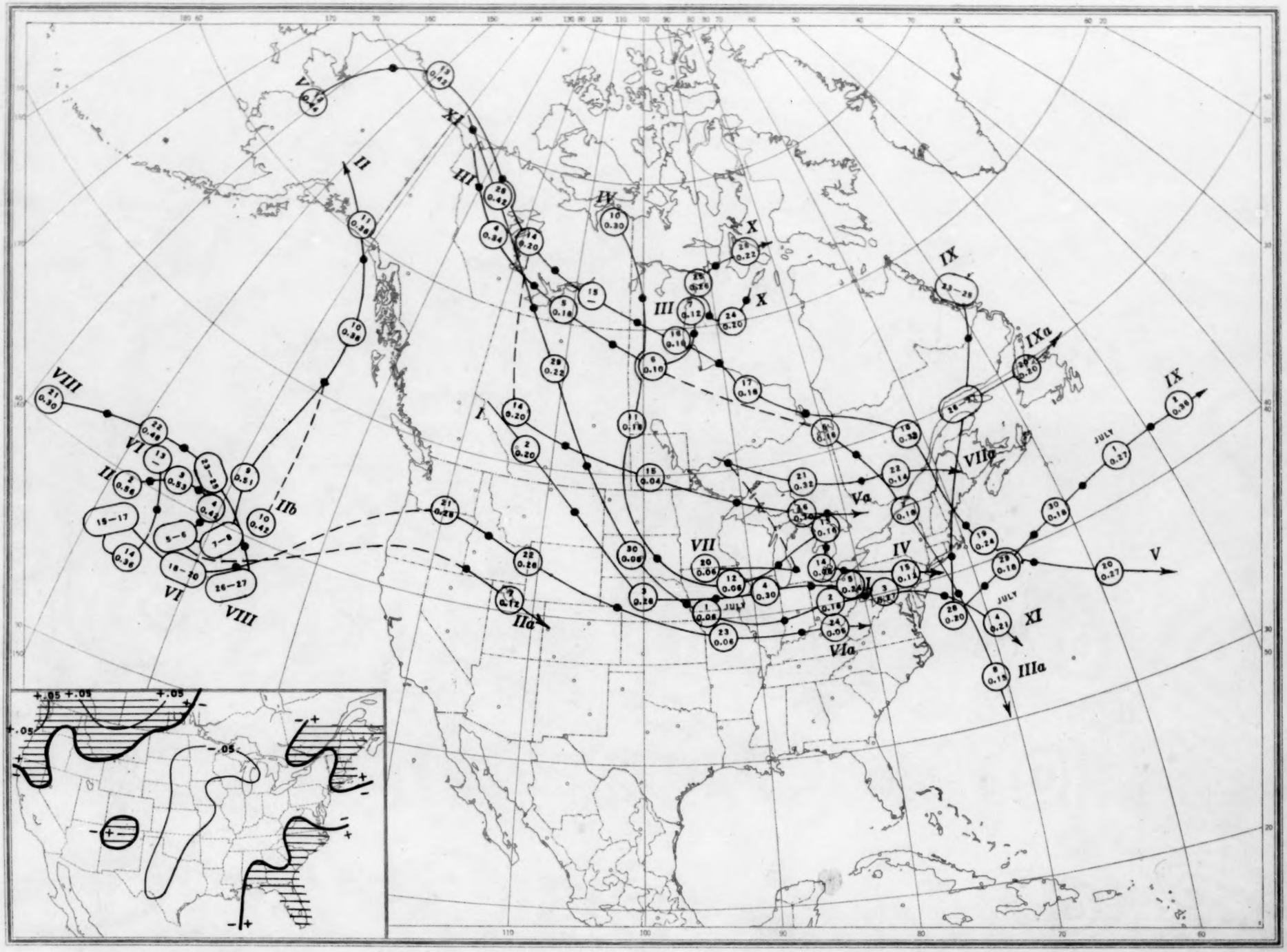
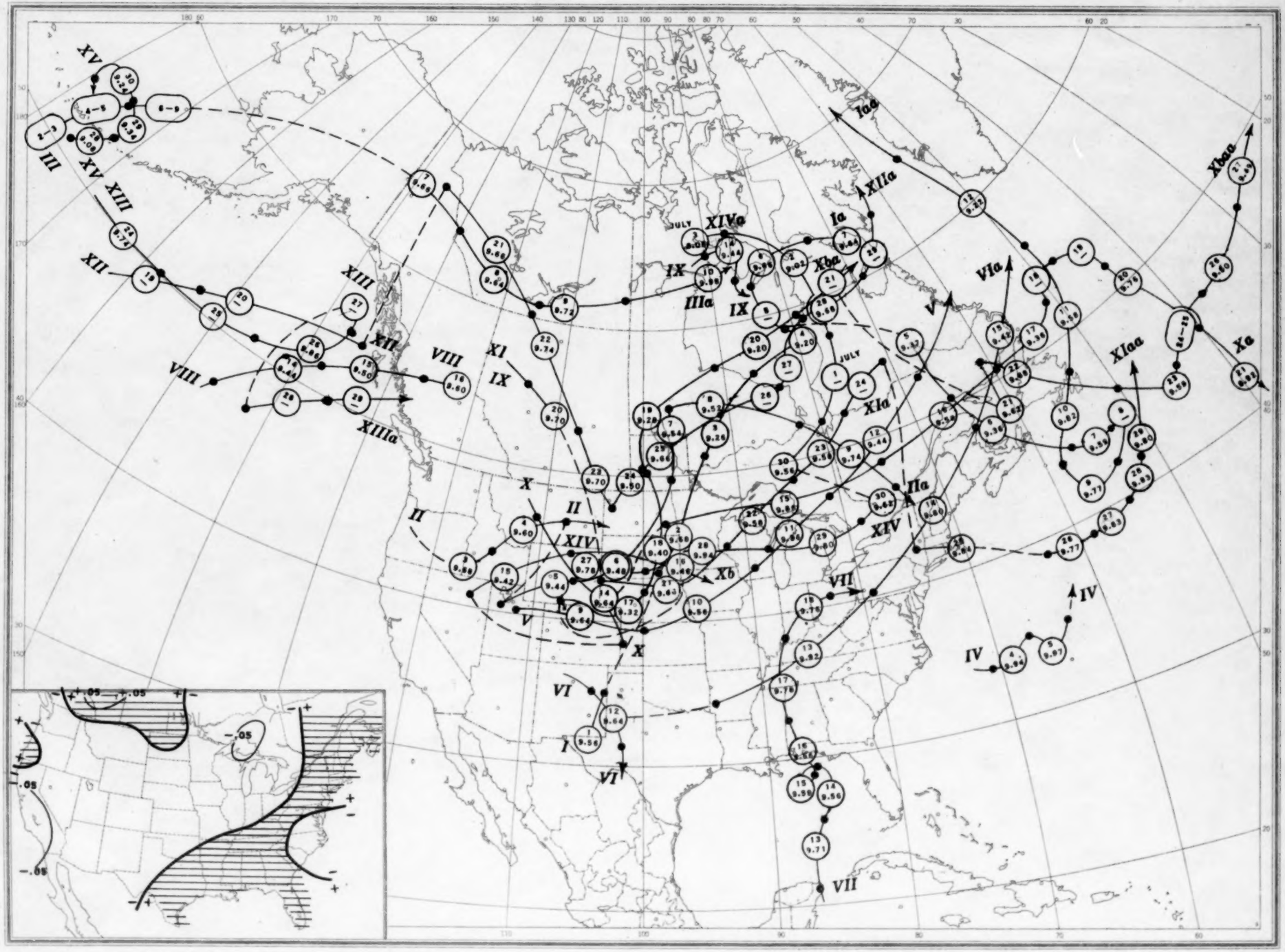


Chart II. Tracks of Centers of Anticyclones, June 1939. (Inset) **Departure of Monthly Mean Pressure from Normal**



Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, June 1939. (Inset) **Change in Mean Pressure from Preceding Month**



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, June 1939

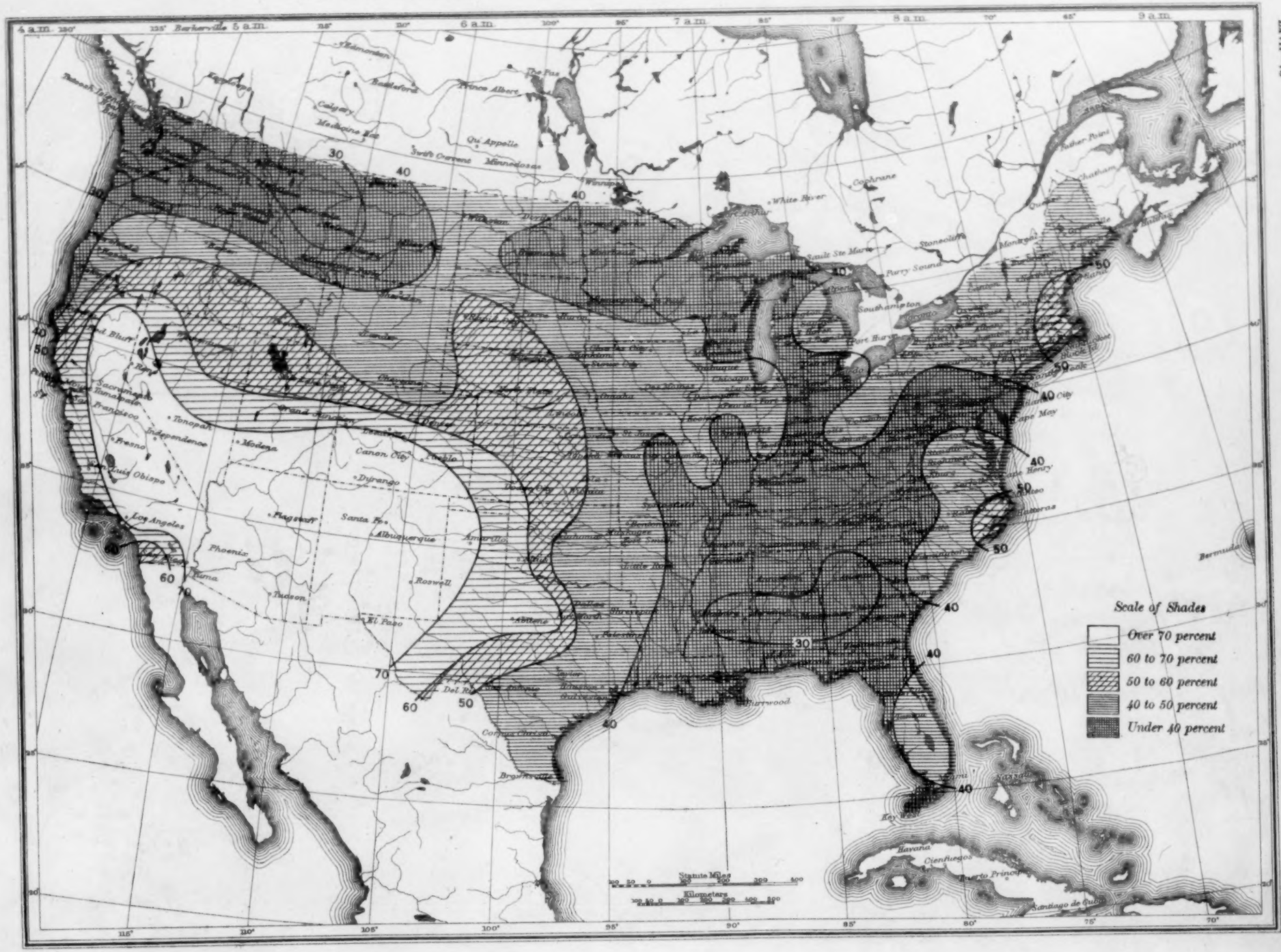


Chart V. Total Precipitation, Inches, June 1939. (Inset) **Departure of Precipitation from Normal**

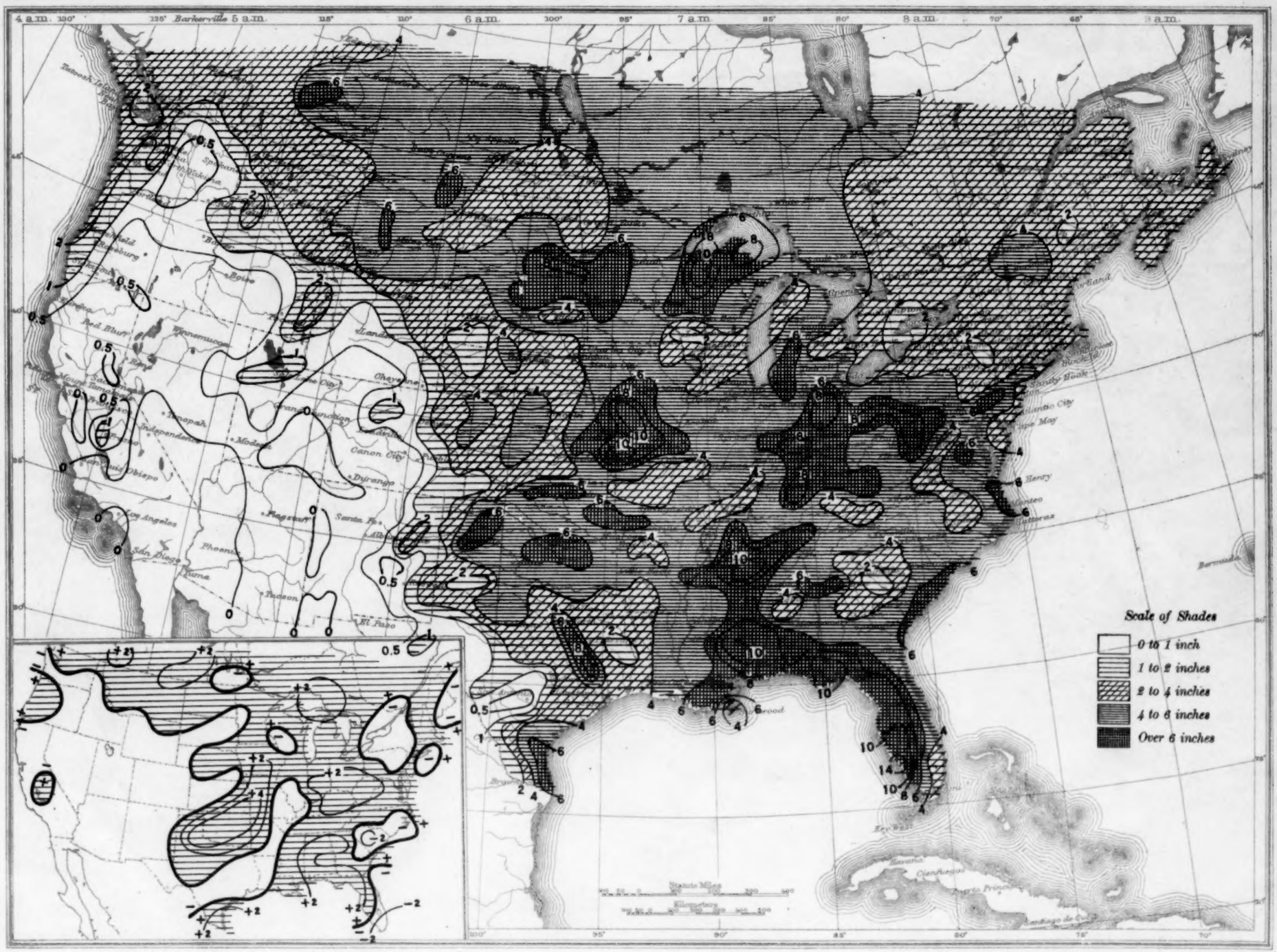


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, June 1939

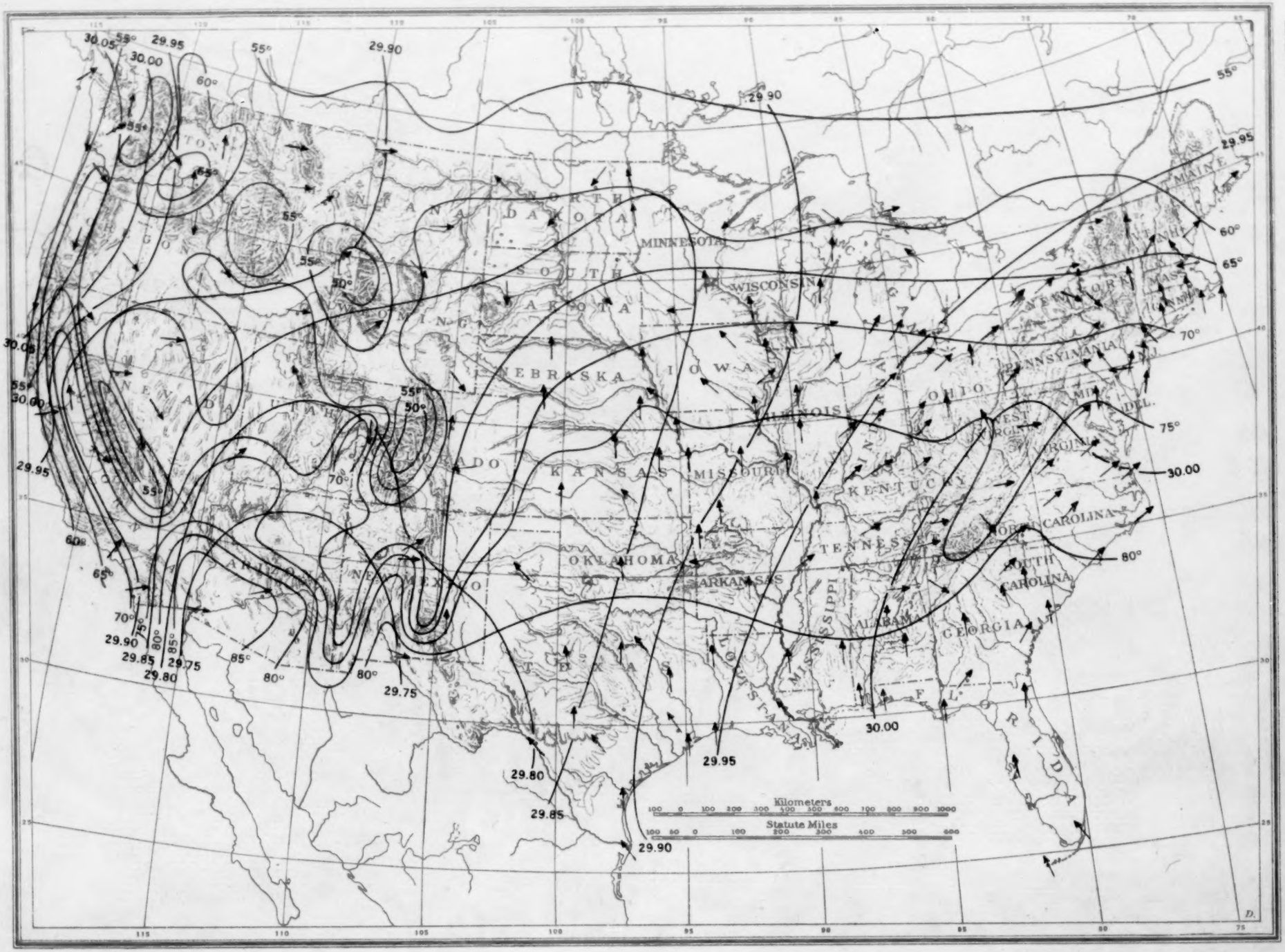


Chart VIII. Isobars (mb) for 1,524 Meters (5,000 ft.) and Isotherms (°C.) and Resultant Winds for 1,500 Meters (m. s. l.) June 1939

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Chart IX. Isobars (mb) Isotherms (°C.) and Resultant Winds for 3,000 Meters (m. s. l.) June 1939

Chart X. Isobars (mb) Isotherms (°C.) and Resultant Winds for 4,000 Meters (m. s. l.) June 1939

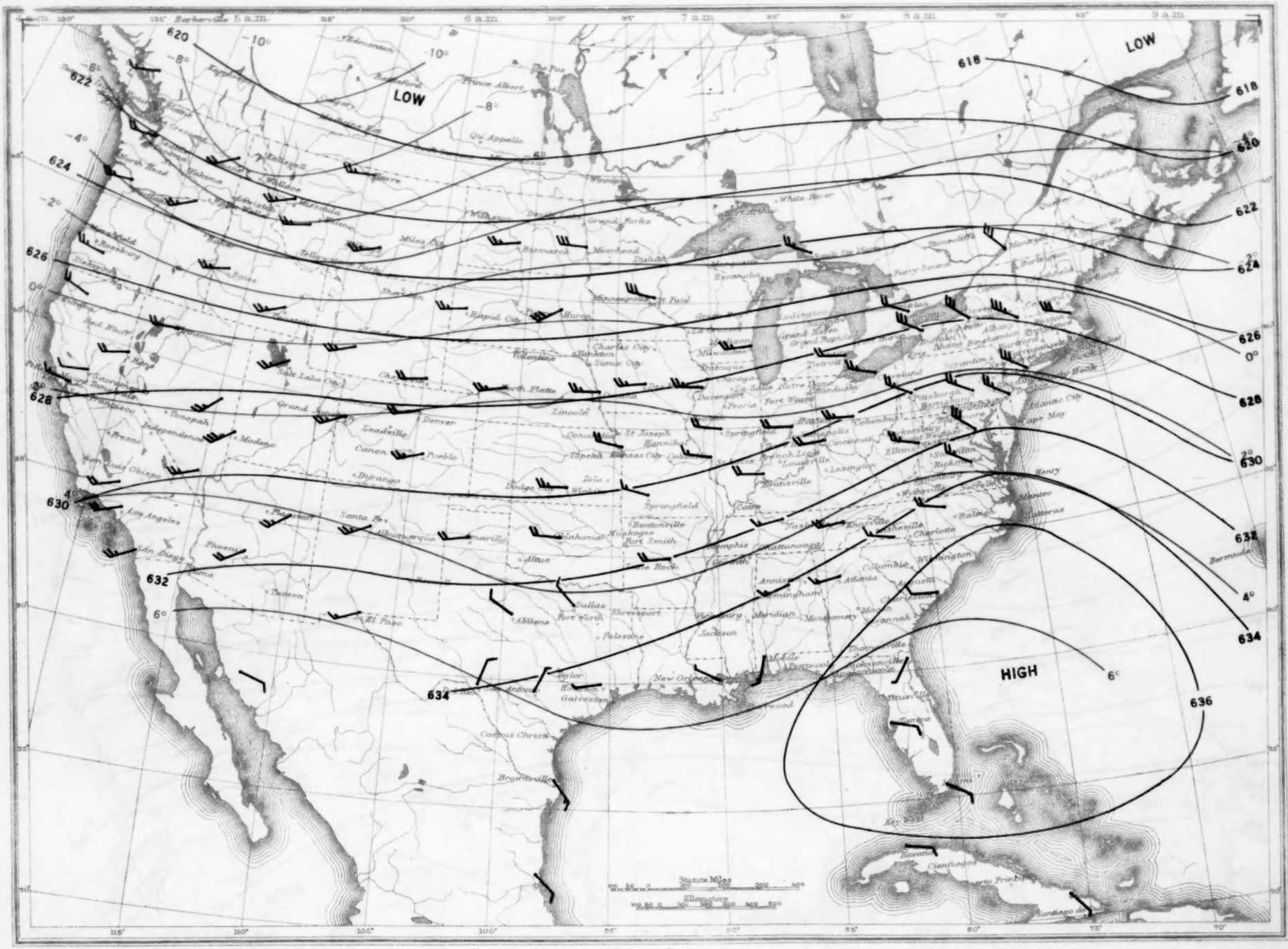


Chart XI. Isobars (mb) Isotherms (°C.) and Resultant Winds for 5,000 Meters (m. s. l.) June 1939

Chart XII. Mean Isentropic Chart, June 1939 (Potential Temperature 310° A.)

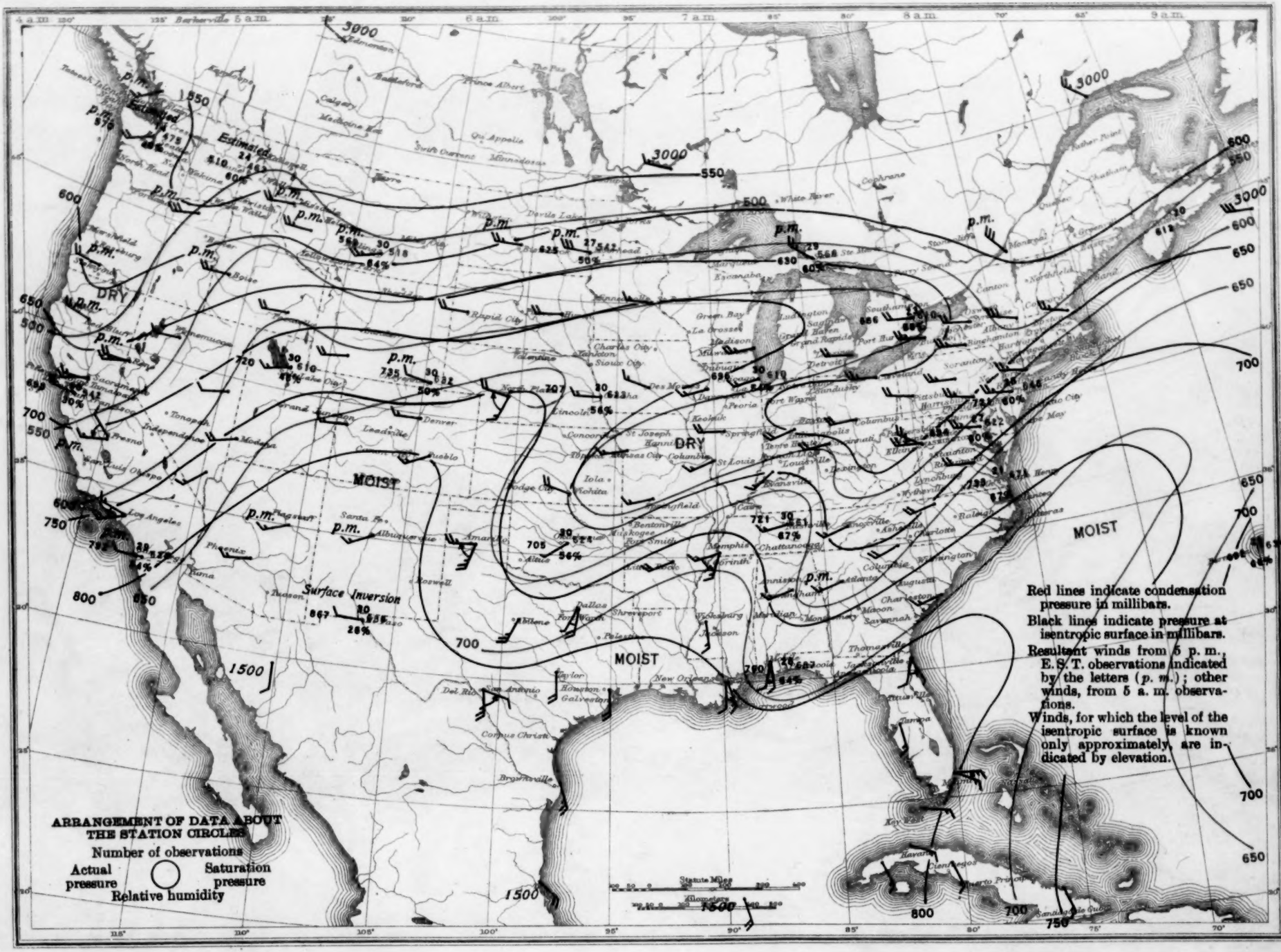
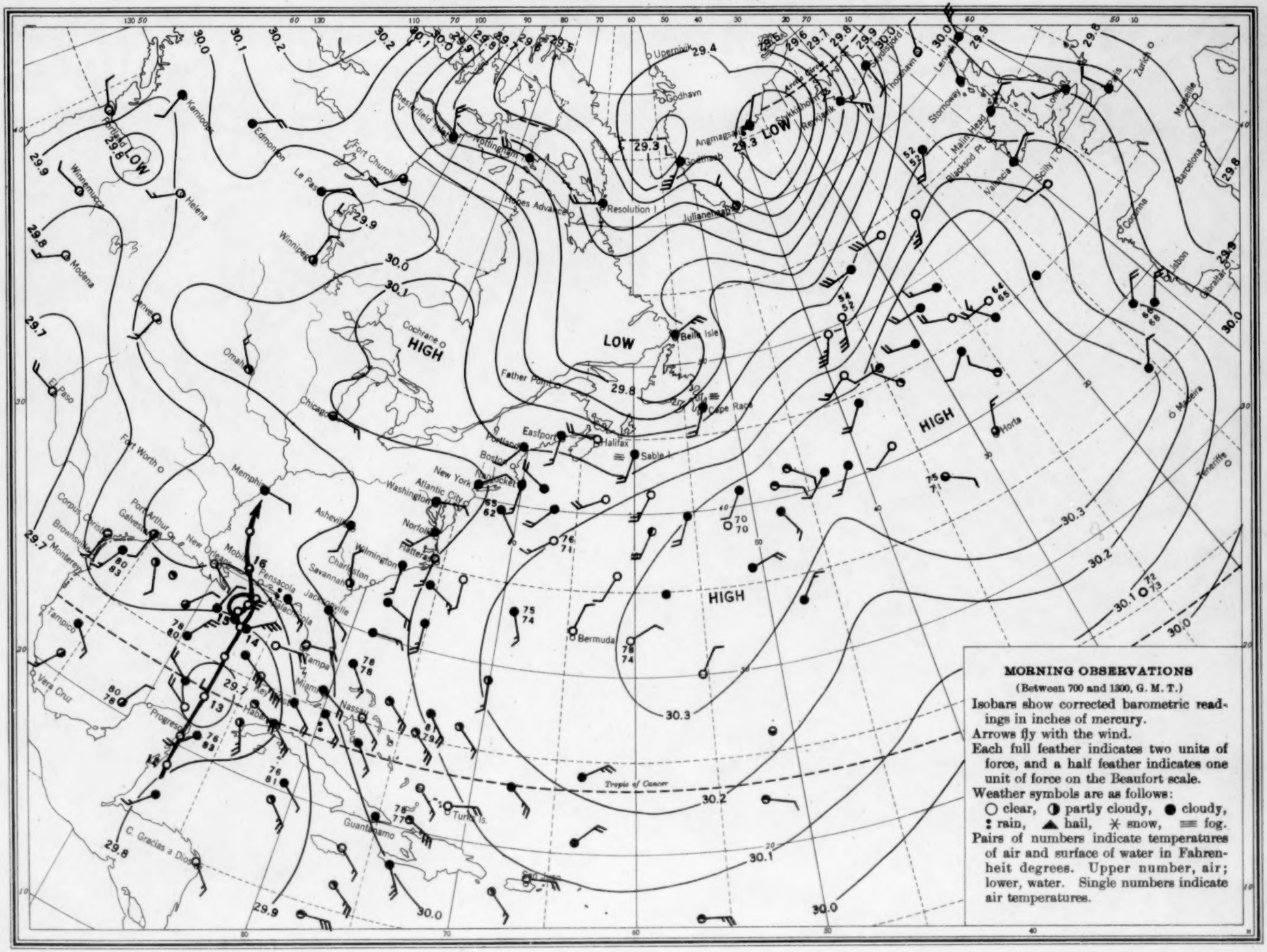

DRY
MOIST
DRY
MOIST
MOIST
Surface Inversion
Red lines indicate condensation pressure in millibars.
Black lines indicate pressure at isentropic surface in millibars.
Resultant winds from 5 p. m. E. S. T. observations indicated by the letters (p. m.); other winds, from 5 a. m. observations.
Winds, for which the level of the isentropic surface is known only approximately, are indicated by elevation.
ARRANGEMENT OF DATA ABOUT THE STATION CIRCLES
Number of observations
Actual pressure
Saturation pressure
Relative humidity

Chart XIII. Weather Map of North Atlantic Ocean, June 13, 1939

Chart XIII. Weather Map of North Atlantic Ocean, June 13, 1939

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Each full feather indicates two units of force, and a half feather indicates one unit of force on the Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, ≡ fog.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

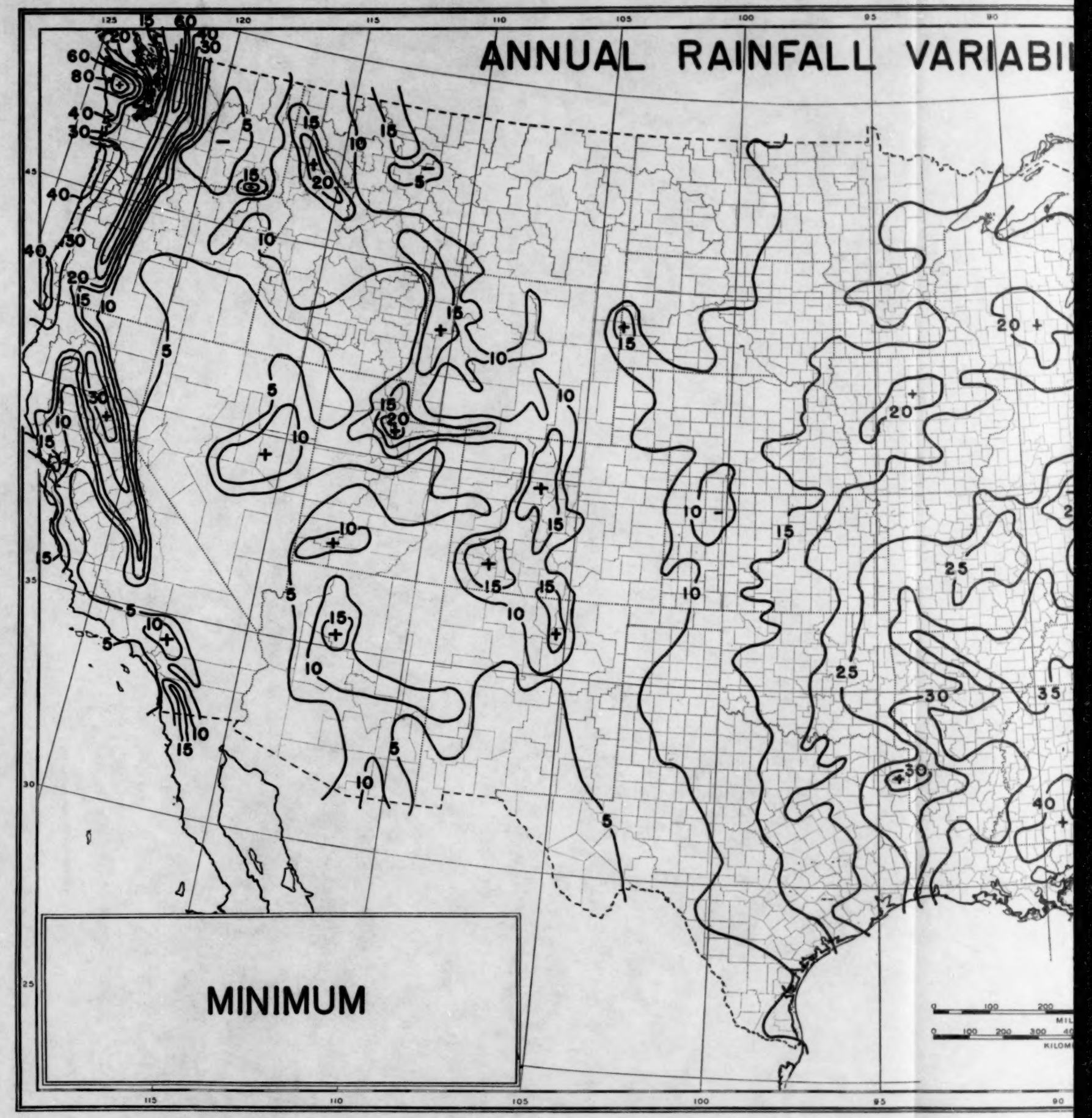
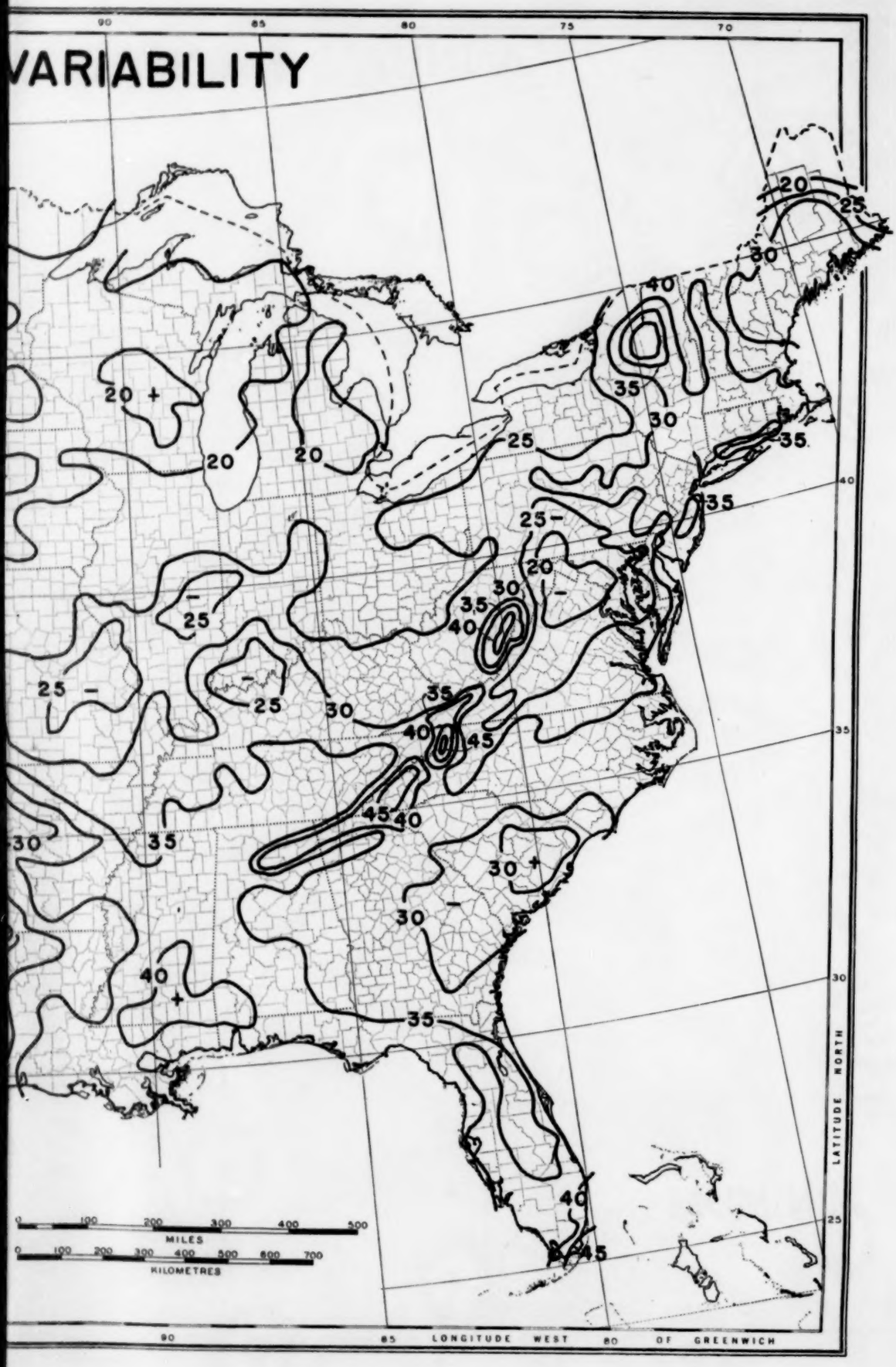


FIGURE 1.


VARIABILITY
90
85
80
75
70
20
25
30
40
35
45
MILES
KILOMETRES
LONGITUDE WEST OF GREENWICH
LATITUDE NORTH

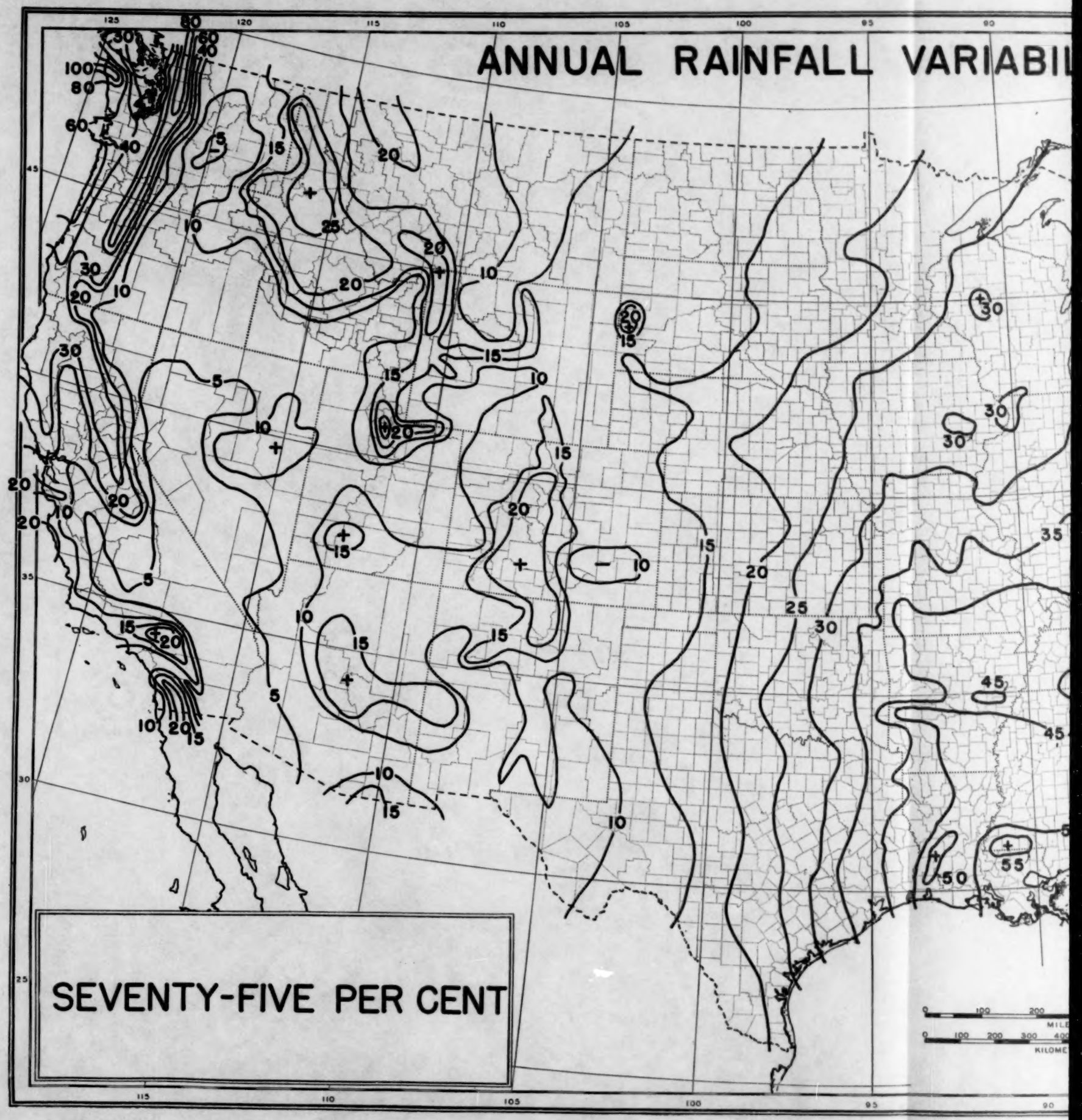
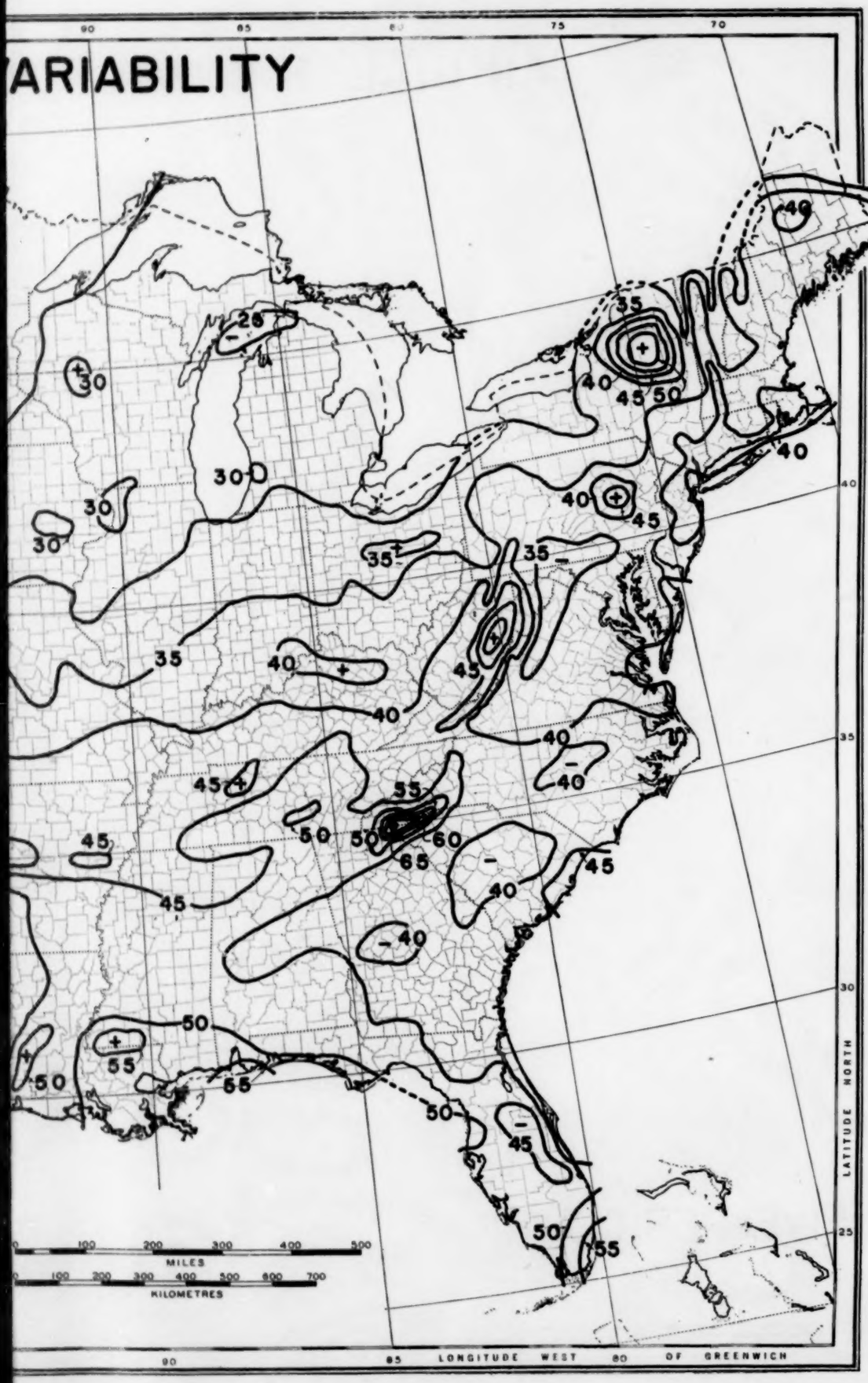

ANNUAL RAINFALL VARIABIL
SEVENTY-FIVE PER CENT
125
120
115
110
105
100
95
90
45
35
30
25
MILE
KILOME

FIGURE 2.


ARIABILITY
90
85
80
75
70
40
35
30
25
LATITUDE NORTH
LONGITUDE WEST OF GREENWICH
MILES
KILOMETRES

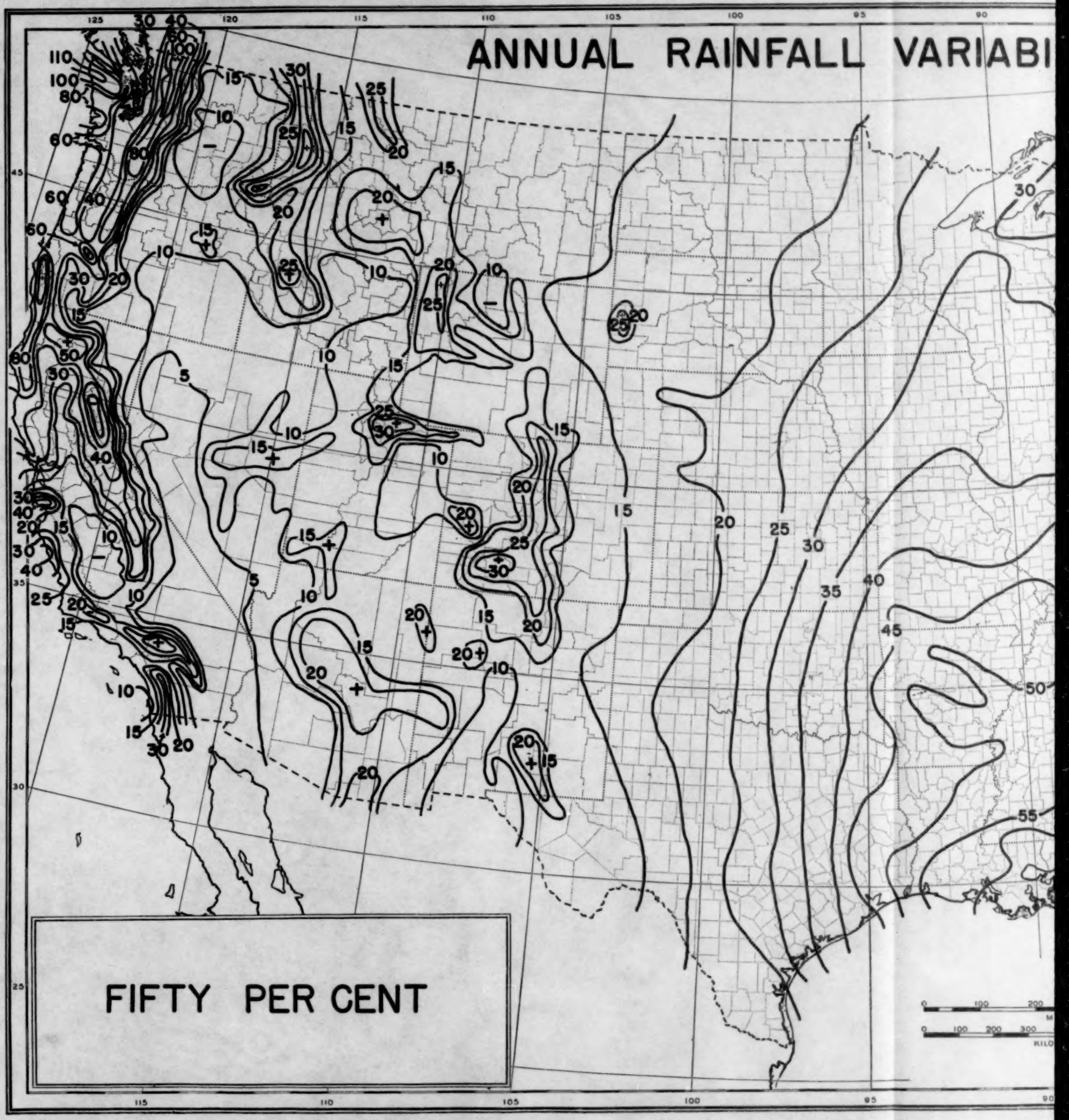
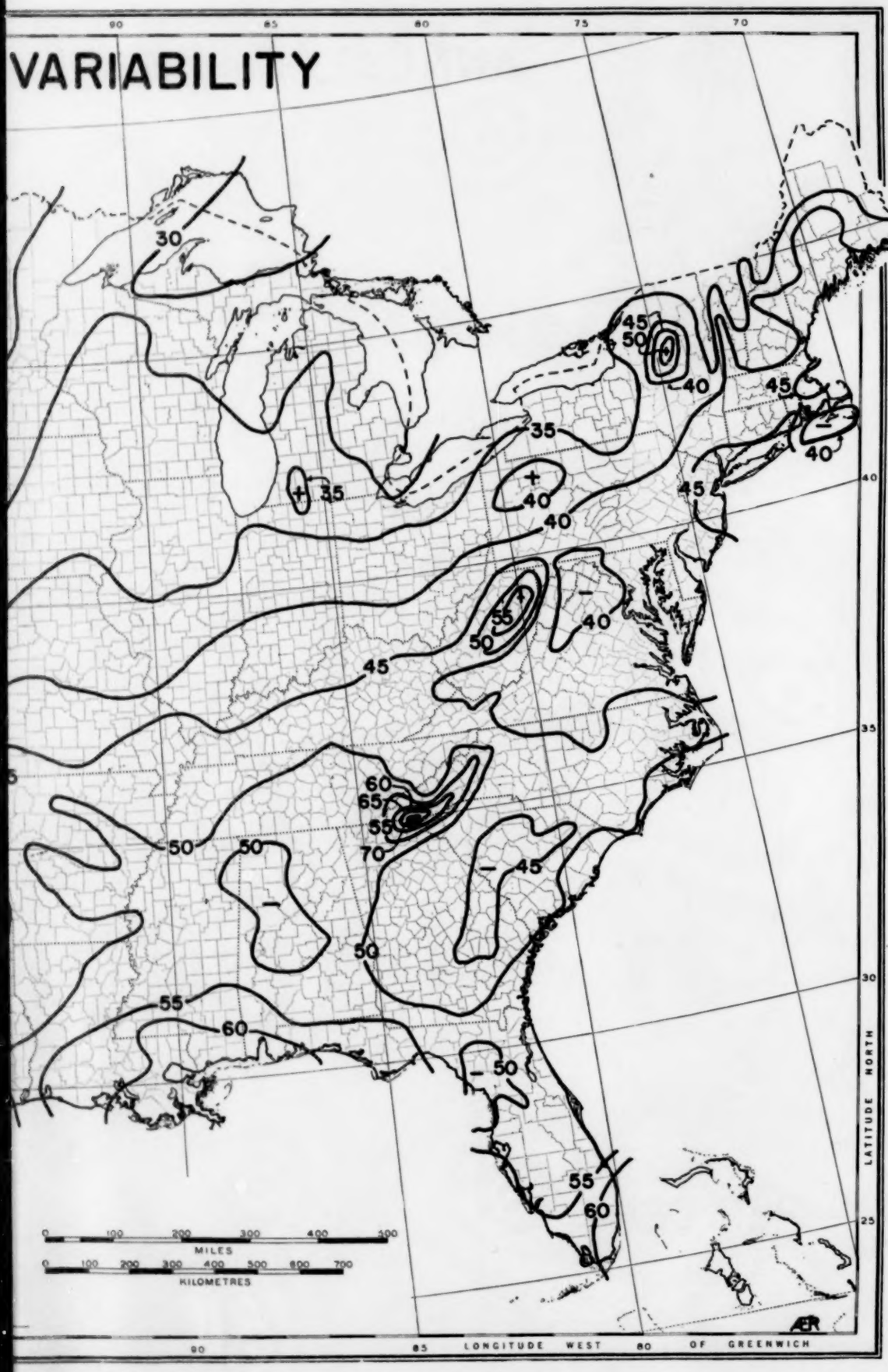


FIGURE 3.


VARIABILITY
90
85
80
75
70
30
35
40
45
50
55
60
65
70
MILES
KILOMETRES
LONGITUDE WEST OF GREENWICH
LATITUDE NORTH

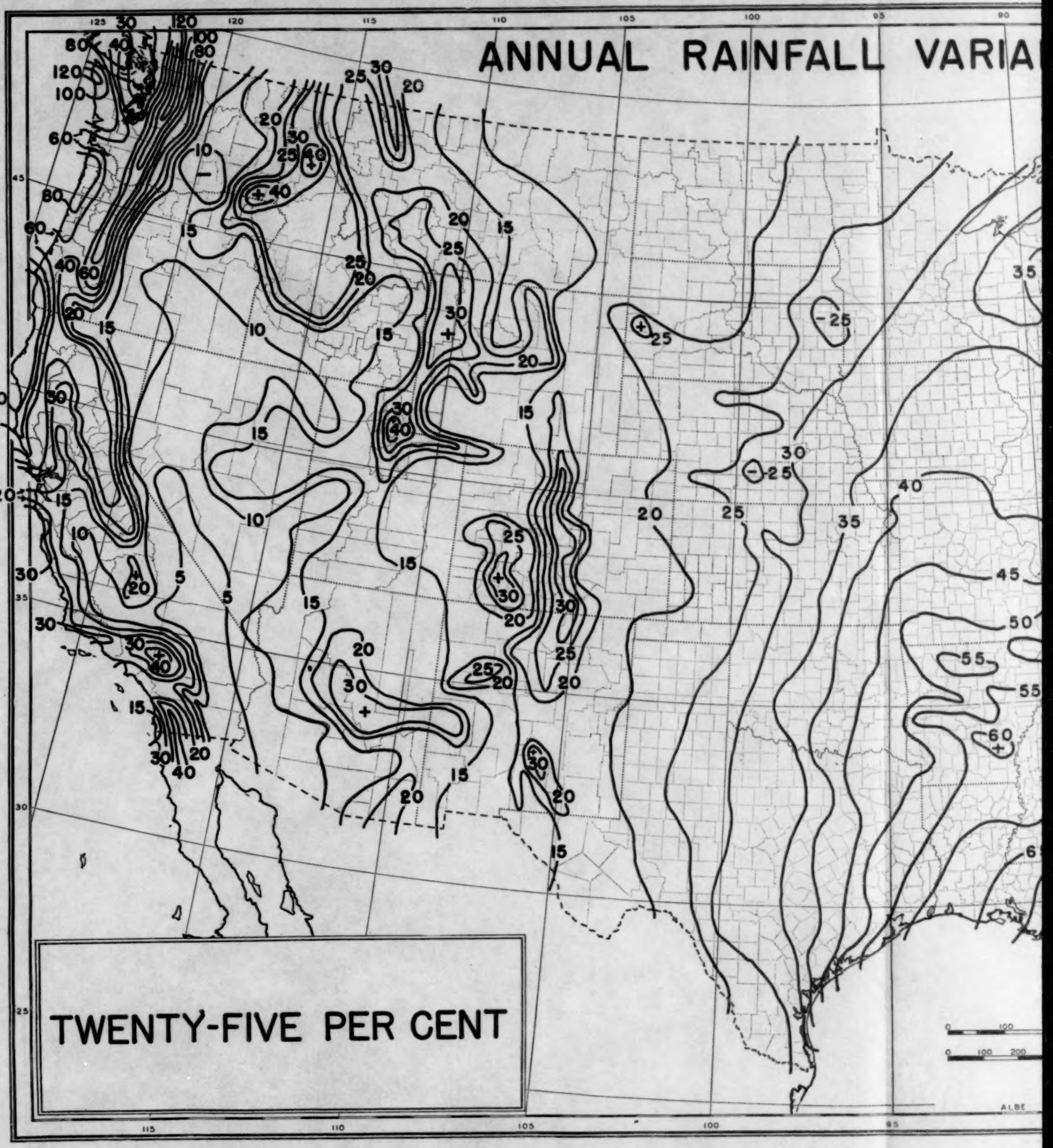
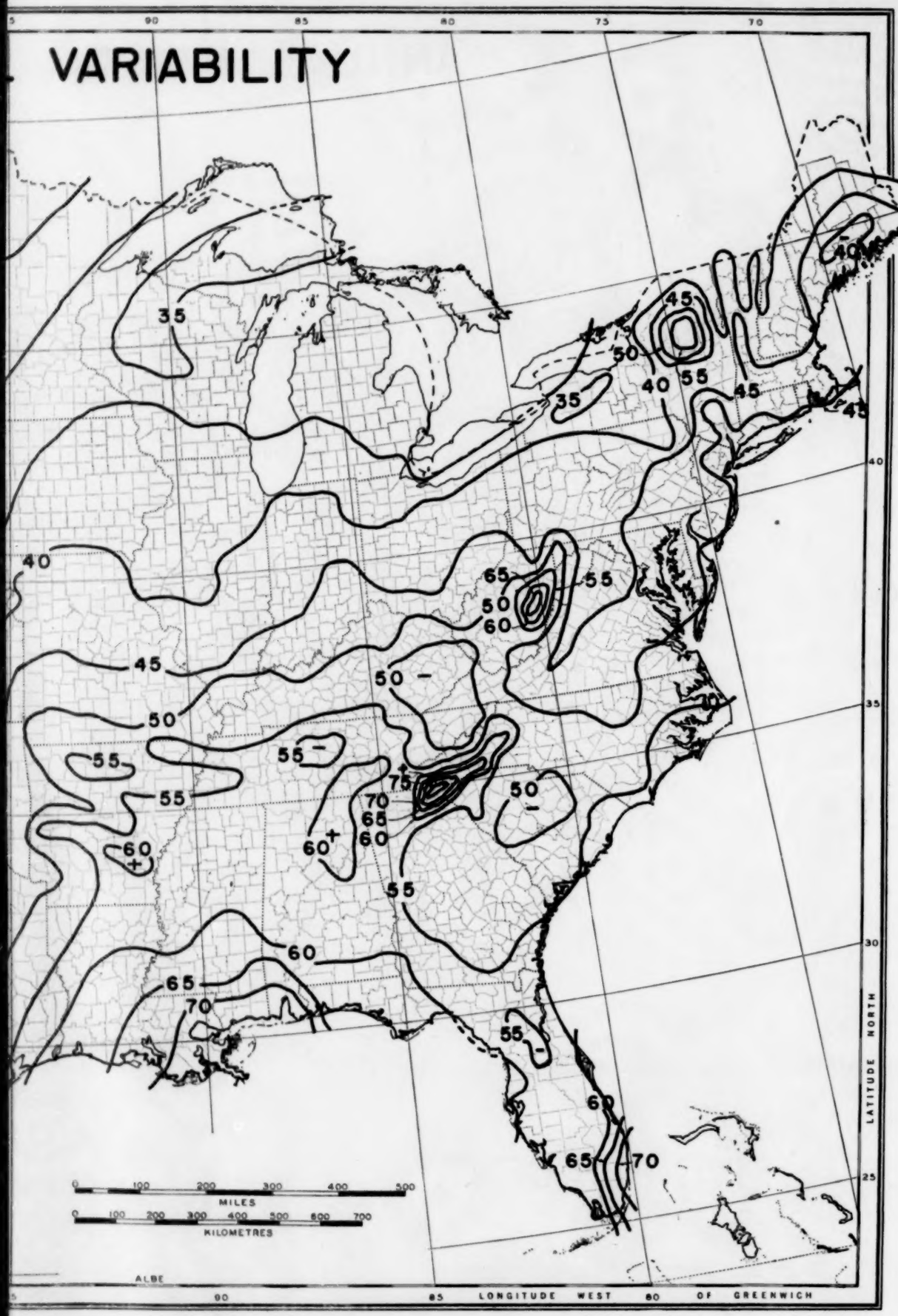


FIGURE 4.


VARIABILITY
35
40
45
50
55
60
65
70
75
MILES
KILOMETRES
LATITUDE NORTH
LONGITUDE WEST OF GREENWICH
ALBE

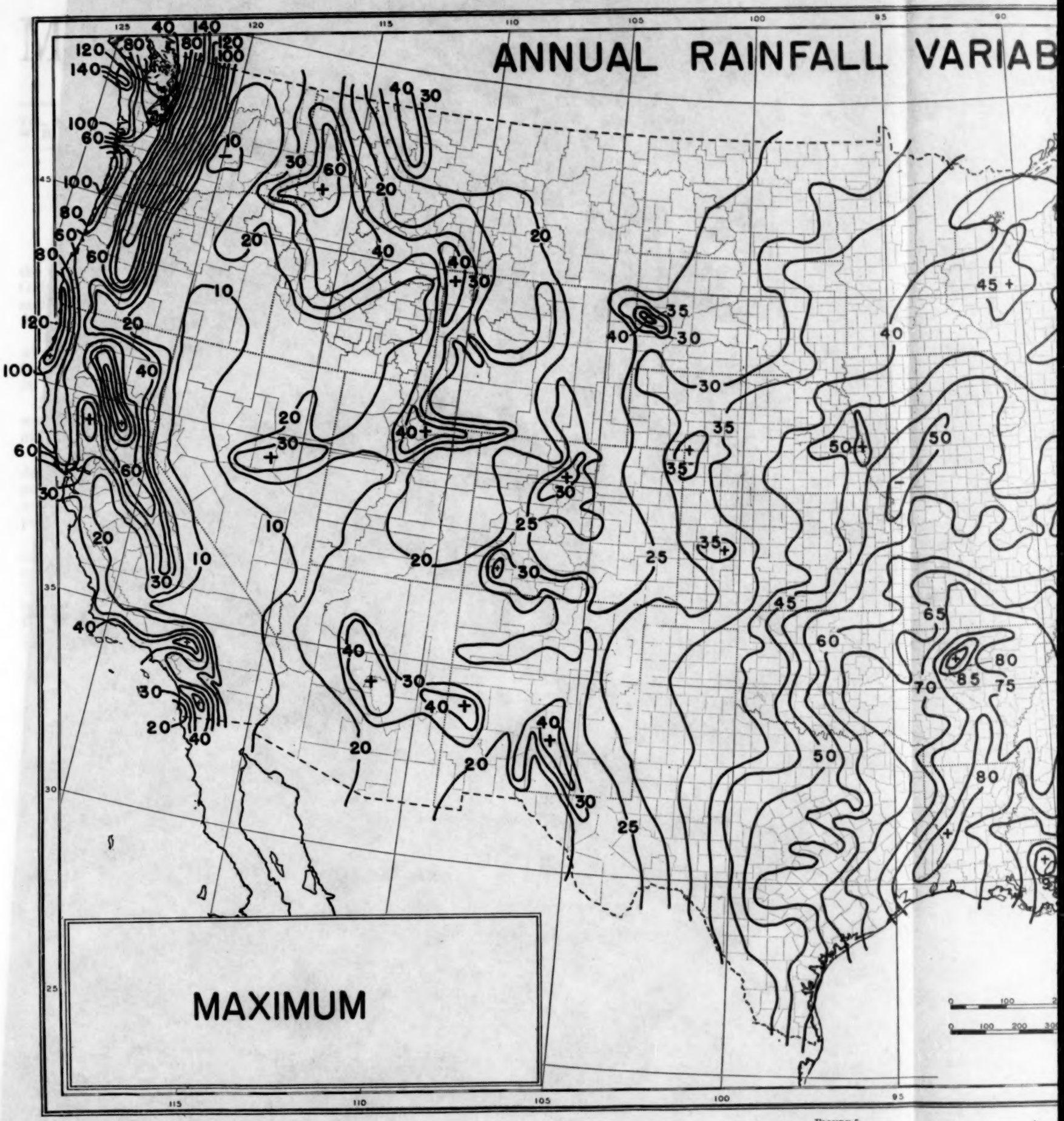


FIGURE 5.

VARIABILITY
90
85
80
75
70
45
40
50
55
60
65
70
75
80
85
90
0 100 200 300 400 500
MILES
0 100 200 300 400 500 600 700
KILOMETRES
90
85
LONGITUDE WEST
80
OF GREENWICH
40
35
30
25
LATITUDE NORTH